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The neural and behavioral correlates of target checking in prospective memory

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ABSTRACT

Prospective memory represents the realization of a delayed intention at the appropriate time or in the appropriate environmental context. Strategic monitoring of the environment is one process believed to be important for successful prospective remembering. Guynn (2003) posited that strategic monitoring is comprised of retrieval mode and target checking. Ample evidence has supported the existence of retrieval mode but less is known about the nature of target checking. Using event related potentials (ERPs), this dissertation examined the neural correlates of target checking in a lexical decision task. Experiment 1 was designed to elucidate the physiological correlates of target checking. The physiological data revealed two ERP components that were associated with target checking: the posterior negativity (300-400ms) and the late positive component (600-1000ms). Both components were present during word and nonword trials, but there were differences in how participants engaged the neural processes associated with the posterior negativity and late positive component for the stimulus types. In Experiment 2, the late positive component was hypothesized to be associated with retrieval processes and this hypothesis was examined by varying the number of prospective memory cues. In Experiment 3, the posterior negativity was hypothesized to reflect neural processes associated with the underlying representation of a stimulus so the wordiness of the nonword stimuli was varied to create stimuli that could activate a lexical but not semantic representation. Based on the findings of the three experiments reported herein, target checking appears to involve an early process involving the representation of a stimulus and a late process involving retrieval of representations from memory.

CHAPTER 1. INTRODUCTION

I. Overview.

Prospective memory (PM) is remembering to execute an intended action at an appropriate moment in the future (Ellis, 1996). Throughout the day, individuals are bombarded with prospective memory tasks such as remembering to purchase milk on the way home from work or remembering to return a book to a colleague. In the milk example, an individual forms the intention of purchasing a gallon of milk after emptying the jug at breakfast. As it may not be wise to realize the intention immediately (i.e., the milk would spoil while sitting in a hot car during the work day), the individual forms the intention of purchasing the milk on the way home from work. The crucial component of this example of prospective memory is that the individual is not able to purchase the milk when the intention is formed and must therefore maintain the intention in memory throughout the workday. On the way home, the individual experiences the appropriate context to execute the intended action (i.e., driving by the grocery store) and the intention is realized (i.e., milk is purchased).

Some theories of prospective memory hold that strategic monitoring must be engaged during prospective memory tasks in order for an intention to be realized (Smith, 2003). Strategic monitoring requires attentional resources and is believed to be supported by two components: retrieval mode and target checking. Retrieval mode is a cognitive state of readiness to encounter a prospective cue whereas target checking is the process of checking the environment for prospective cues. Several studies have examined the neural correlates of strategic monitoring; however, only one study has sought to distinguish the neural correlates of target checking and prospective retrieval mode. To address this limitation of the existing literature, this dissertation used event-related brain potentials (ERPs) in three experiments to characterize the neural correlates of target checking.

Experiment 1 was designed to identify ERP correlates of target checking within the context of a lexical decision task that has been extensively used to study the behavioral correlates of strategic monitoring in PM (Marsh et al., 2003; Smith, 2003). In this experiment, participants completed blocks of lexical decision tasks with an embedded prospective memory component (pressing a key when a target word or nonwords was encountered). Prospective cues were varied such that one PM block contained word cues and another block contained nonwords cues. The physiological data revealed two ERP components associated with target checking: the posterior negativity (300-400ms) and the late positive component (LPC; 600-1000ms).

Experiment 2 was designed to examine the contribution of a stable lexical and semantic representation to the generation of the posterior negativity. In Experiment 1, participants were able to engage neural processes associated with the posterior negativity specifically for words when the PM cue was a word; in contrast, this modulation of the ERPs was sensitive to both words and nonwords when the PM cues were nonwords. Words have lexical and semantic representations, which differentiate them from nonword stimuli. Target checking could be supported by a process that operates like an attentional filter by facilitating information relevant to the PM task and perhaps the posterior negativity is associated with this filter. To determine if the posterior negativity is associated with an attentional filter that differentiates stimuli based on lexical or semantic representations, the "wordiness" of the nonword stimuli was varied in Experiment 2 by using two types of nonwords as PM cues (i.e., orthographic neighbor nonwords (i.e. plip) and letter string nonwords (i.e. ornb)). If the posterior negativity reflects an attentional filter that uses semantic representations, the posterior negativity should have distinguished words from letter string and wordy nonwords. If the posterior negativity reflects an attentional filter that uses lexical representations, the posterior negativity should have distinguished words and wordy nonwords from letter string nonwords. The results of Experiment 2 indicate that the posterior negativity may function as an attentional filter, but participants may circumvent this filter when completing PM tasks as the posterior negativity was not present for orthographic neighbor nonwords.

Experiment 3 was designed to examine the nature of the processes contributing to generation of the LPC associated with target checking and tested the hypothesis that the LPC is associated with memory retrieval processes. To test this hypothesis, the number of prospective cues was varied between blocks of trials (i.e., two or six) in Experiment 3. If the LPC is associated with retrieval processes, then this component of the ERPS should have distinguished the two prospective cue condition from the six prospective cue condition. The results of Experiment 3 indicate that the amplitude of the LPC was greater for the six cue condition than the two cue condition, which is consistent with the hypothesis that the LPC is associated with memory retrieval processes.

II. Characteristics of Prospective Memory Tasks.

Because failures of prospective memory can have dramatic consequences such as failing to take a medication at a prescribed time or failing to extinguish a candle before going to sleep, scientists have the important task of determining the cognitive, behavioral, and neurological underpinnings of prospective memory. McDaniel and Einstein (2007) have outlined five critical components of prospective memory that need to be understood and therefore should be captured in a laboratory paradigm. One key component of prospective memory is that the intention is completed at a future point in time, so it is critical for laboratory tasks to have a delay between the formation of an intention and the opportunity to realize the intention. A second component is that prospective memory is embedded in an ongoing activity. In the example of buying a gallon of milk, individuals are engaged in an activity (driving home from work) and must disengage from that activity (stop at a grocery store) in order to successfully execute an intended action (purchasing a gallon of milk). In the laboratory, researchers mimic this experience by engaging participants in an ongoing activity such as performing a lexical decision task (i.e., deciding whether a letter string is a word or nonword) that has as an embedded prospective memory component (i.e., making an additional response when the word "cow" is encountered). Third, the window for response initiation should be cued by time, an event, or an activity. For instance, removing a pan from the oven after 10 minutes of baking requires that the intention be executed within a couple minutes in order to avoid undercooking or burning one's cookies. Laboratory prospective memory tasks impose this constraint by limited the time frame a participant has to make a prospective response (e.g., a response must be made within two trials of encountering the prospective cue). Fourth, the time frame for response execution should be limited. McDaniel and Einstein (2007) argue that the execution time frame should be on the order of seconds, minutes or hours to distinguish prospective memory tasks from other tasks that may take months to complete (e.g., writing grants or planning a trip). Fifth, there must be an intention, meaning that the participants must consciously intend to complete a prospective memory action.

The above parameters as outlined by McDaniel and Einstein (2007) provide a general approach for laboratory investigations of prospective memory including time-based, event-based, and activity-based. For example, consider a study of event-based prospective memory by McDaniel, Einstein, Guynn and Brenesier (2004). The ongoing task for this experiment was for participants to rate a word on various dimensions such as pleasantness and concreteness using a five-point scale. Prior to beginning this task, participants were told that they had the additional task of remembering two words (spaghetti and needle) and pressing the "l" key when they encountered those words in the experiment. The words spaghetti and needle served as the prospective cues in this example and the action of pressing the "l" key was the intention. The time frame for response initiation and execution was limited to the trials in which the prospective cues were presented. The majority of prospective memory laboratory studies follow this general procedure with minor modifications for time-based (pressing a "F8" every 5 minutes) and activity-based studies (press "F8" after completing the first experimental block).

III. The Multiprocess Theory of Prospective Memory

Individuals engage in numerous prospective memory tasks in a day such as attaching a file to an e-mail before sending it or calling a sibling on his/her birthday. Each prospective memory tasks can have different demands. For example, taking a medication 15 minutes after eating requires monitoring time closely, but returning a book to a colleague does not have a critical time constraint. Thus, an adaptive prospective memory system would utilize multiple processes to allow for successful prospective remembering under a variety of conditions. McDaniel and Einstein's (2000) multiprocess theory of prospective memory offers one framework of such an adaptive system.

The multiprocess theory of prospective memory rests on three critical assumptions. First, successful prospective remembering can be the result of either strategic monitoring (i.e., preparatory processes requiring attentional resources; Smith, 2003) or spontaneous retrieval (i.e., the relatively automatic retrieval of intentions from memory when the appropriate cue is encountered). Second, task demands determine whether an individual relies on spontaneous retrieval or strategic monitoring to support prospective remembering. Third, individuals are generally biased towards using spontaneous retrieval because strategic monitoring requires attentional resources that could otherwise be devoted to ongoing activities. There is evidence to support the first and second assumptions of the multiprocess theory but the third assumption has not been demonstrated in the literature.

The findings of several studies provide support for the first assumption of the multiprocess theory, which describes two processes, strategic monitoring and spontaneous retrieval, that support successful prospective remembering. Evidence for strategic monitoring has been demonstrated in behavioral studies as the costs in reaction times when a PM component is added to the ongoing activity. In a typical prospective memory experiment examining strategic monitoring, participants complete two blocks (PM and NoPM) of trials (Marsh et al., 2003; Smith, 2003). A consistent finding from these studies is that reaction time is slower for PM blocks than for NoPM blocks. This slowing is attributed to the addition of cognitive processes and has been observed using a variety of ongoing activities and PM cues (Burgess et al., 2001; Guynn, 2003; Marsh, Hicks, Cook, Hansen & Pallos, 2003; Smith, 2003; Smith & Bayen, 2004; Einstein et al., 2005).

Because spontaneous retrieval represents the relatively automatic retrieval of intentions from memory when the appropriate cue is encountered, evidence for spontaneous retrieval would represent high levels of prospective memory with no or minimal reaction time costs to the ongoing activity. A study by Einstein, McDaniel, Shank and Mayfield

(2002) found high prospective memory performance (94%) and negative reaction time costs (-73ms) for a prospective memory block. Einstein et al. (2002) provides evidence that strategic monitoring is not crucial to prospective memory performance as reaction time costs were not significant in PM blocks with high PM accuracy.

Einstein et al. (2005) provided additional evidence for the existence of spontaneous retrieval by presenting prospective cues in a block in which participants would not be engaging strategic monitoring because the prospective cues were not task relevant. In the experiment, participants completed one prospective memory block and were given an interleaving activity of a lexical decision task prior to completing the next prospective memory block. Einstein et al. (2005) expected slower reaction times when participants encountered prospective cues from the previous block in their current lexical decision task. This slowing would occur as participants suppress the now irrelevant delayed intention. The results from Einstein et al. (2005) Experiment 5 were consistent with the spontaneous retrieval view as the reaction times for prospective cue items in the lexical decision task were significantly slower than the other stimuli.

The next step in studying strategic monitoring and spontaneous retrieval in PM is determining when an individual will utilize one process or the other. McDaniel and Einstein (2007) have begun this pursuit and summarized six task demands that are important in determining whether individuals use spontaneous retrieval or strategic monitoring. First, if the prospective cue receives focal processing during retrieval, an individual is more likely to rely on spontaneous retrieval for completing the prospective memory task. Focal processing means that the ongoing task encourages processing of some attribute the cue that is relevant to task performance. An example of focal processing can be seen in the semantic category task used by Einstein et al. (2005). The focal processing manipulation of Einstein et al. (2005) was that an embedded prospective component was either pressing a key in response to a word (e.g., tortoise, focal condition as words are central to the task) or a syllable (e.g., tor, nonfocal condition as syllables are not central to the task). The results revealed slower reaction times for the nonfocal trials (indicating strategic monitoring as it is a capacity consuming process) than the focal trials (indicating spontaneous retrieval as it is relatively automatic), which is a finding that converges with predictions derived from the Multiprocess Theory.

The second important task characteristic for determining whether individuals use spontaneous retrieval or strategic monitoring is the demands of the ongoing task. Specifically, more engaging ongoing tasks allow fewer resources to be devoted to strategic monitoring thereby requiring the individual to rely on spontaneous retrieval for successful prospective remembering. The N-Back task is an ongoing activity with high cognitive demands and West, Bowry and Krompinger (2006) used this behavioral paradigm (1-back and 3-back) to examine the neural correlates of prospective memory. West et al. (2006) observed two modulations of the ERP that distinguished the 1-back and 3-back conditions. The major finding was a sustained modulation (700-1200ms) over the right frontal-central region for the 1-back but not 3-back condition. A sustained modulation is indicative of strategic monitoring so the results of West et al. (2006) provide evidence that spontaneous retrieval is utilized when the ongoing activity required more attentional resources in the 3-back condition.

McDaniel and Einstein’s (2007) third important task demand is target cue distinctiveness. If the prospective memory cues are salient (e.g., presented in uppercase letters) to the other items in the ongoing task (e.g., presented in lower case letters), the prospective memory targets will lead to spontaneous retrieval. West, Wymbs, Jakubek and Herndon (2003) provide evidence to support the hypothesis that cue distinctiveness influences whether one utilizes strategic monitoring or spontaneous retrieval. To manipulate cue distinctiveness, West et al. (2003) varied the display color of the ongoing activity stimuli and prospective cue stimuli in two blocks (uniform and mixed) of trials. In the uniform condition, all ongoing activity stimuli were displayed in the color gray and the prospective cues were displayed in green, cyan or yellow. In the mixed condition, the ongoing activity stimuli were displayed in gray, red, blue or violet while the prospective cues were presented in green, cyan or yellow. The data revealed slower reaction times in the mixed condition (when cue distinctiveness was present) relative to the uniform condition supporting the idea that participants may have relied on spontaneous retrieval to complete the PM task in the uniform condition and strategic monitoring in the mixed condition.

The fourth, fifth and sixth important task demands outlined by McDaniel and Einstein (2007) are associativity of the target cue with the intended action, the importance of the prospective memory task, and the retention interval. If the prospective memory cue (pizza) is highly associated with the prospective action (eating dinner), the individual is more likely to rely on spontaneous retrieval, as the strong association can support spontaneous retrieval of the intended action. If a prospective memory task is of high importance (checking blood sugar levels), an individual is more likely to engage in strategic monitoring and devote attentional resources to that task (Smith & Bayen, 2004; Kliegel, Martin, McDaniel & Einstein, 2004). Finally, when retention intervals are longer individuals may favor spontaneous retrieval.

In addition to task demands, McDaniel and Einstein (2007) also propose that individual differences in personality variables or working memory capacity may play a role in determining whether individuals rely on spontaneous retrieval or strategic monitoring. For example, personality variable such as conscientiousness and compulsiveness may lead individuals to engage in more strategic monitoring. Similarly, individuals with high working memory capacity would have more attentional resources available to devote to strategic monitoring.

IV. The Preparatory Attentional and Memory Processes Theory

Smith's (2003) Preparatory Attentional and Memory processes (PAM) theory of prospective memory posits that capacity consuming preparatory processing (strategic monitoring) must be engaged to monitor the environment for possible prospective memory cues. These preparatory processes could initiate a recognition check when a relevant environmental event is encountered or the preparatory processes may include rehearsing the critical target event. According to PAM, successful prospective memory requires the engagement of preparatory processes and their absence would result in the failure to realize an intention when a prospective cue is encountered. This theory differs from the Multiprocess Theory, which holds that there are contexts in which participants would not rely on strategic monitoring. The most common form of evidence for preparatory processes is reaction time costs to the ongoing activity when a PM component is added to the task.

The first study to describe reaction time costs to an ongoing activity during prospective memory blocks was a PET study by Burgess, Quayle and Frith (2001). In this study, participants completed three blocks of trials including a NoPM block and two PM blocks. The data revealed slower reaction times in both PM blocks relative to the NoPM block. Therefore, Burgess et al. (2001) provided evidence that additional processing is required when a prospective memory component is added to an ongoing task. The generality of this effect is seen in lexical decision tasks (Marsh, Hicks, Cook, Hansen & Pallos, 2003; Smith, 2003; Smith & Bayen, 2004), sentence completion tasks (Einstein et al., 2005), and a continuous detection task (Guynn, 2003). This result also extends to studies using the prospective cue of a semantic category (Marsh et al., 2003; Guynn, 2003) and a syllable (Einstein et al. 2005).

Cohen, Jaudas and Gollwitzer (2008) provided further evidence that the slowing observed during prospective memory blocks is due to the addition of a cognitive process (i.e., monitoring) rather than the division of attentional resources. Participants completed the ongoing activity of a lexical decision task with the prospective task of pressing a key in response to a cue. The number of cues was varied with participants having 1, 2, 3, 4, 5, or 6 PM cues. The data revealed slower reaction times for the PM condition consistent with previous findings. Additionally, Cohen et al. (2008) found a linear relationship between the number of PM cues and reaction time for the ongoing activity such that participants in the 6 cue condition had the greatest reaction time costs. These findings indicate that participants engage preparatory processes during prospective memory tasks and they are able to engage more preparatory processes when they have more than one prospective cue.

Research has also shown that task demands, such as the importance of the prospective memory task, can increase the reaction time costs to the ongoing activity indicating that monitoring is strategic. For example, Smith and Bayen (2004) manipulated the emphasis placed on the prospective memory task embedded in a color matching ongoing activity. Participants saw four rectangles (each of a different color) presented sequentially. After the fourth rectangle, participants saw a word displayed in color and were to press a key if the color was the same as one of the four rectangles. The prospective memory task was to press a key when words that were PM cues appeared in the color matching tasks. To manipulate the importance of the ongoing activity, the researchers emphasized accuracy on either the color matching task or the prospective memory task. The results revealed greater reaction time costs when emphasis was placed on the prospective task (579ms) relative to when emphasis was placed on the ongoing task (371ms). This finding supports the idea that monitoring can be strategic as participants could flexibly allocate resources to strategic monitoring depending upon the importance of the task.

Marsh, Hicks and Cook (2006) provide further evidence that strategic monitoring is flexible. If monitoring is strategic, Marsh et al. (2006) posited that participants would not engage in monitoring for prospective cues until the context in which they expected to execute the intended action was encountered. To test this idea, Marsh et al. (2006) had participants complete three blocks of trials (lexical decision block, questionnaire block and lexical decision block). Participants were informed at the beginning of the experiment that they would have the prospective task of making a key press whenever an animal word was encountered. The twist in this experiment was that the participants were told that animal words would not be presented until the third block of experimental trials. Marsh et al. (2006) found only reaction time costs in the third block of trials, which was the context in which the participants expected to encounter the prospective memory target. These results provide evidence for the strategic allocation of monitoring as reaction times slowed only during trials in which participants expected to execute the delayed intention.

V. Processes Underlying Strategic Monitoring

The prospective memory literature provides compelling evidence that strategic monitoring is important for successful prospective remembering, at least in some contexts. One limitation of the PAM theory is that it does not specify the nature of the processes underlying strategic monitoring. In contrast, Guynn's (2003) retrieval mode plus target-checking model (RM + TC) proposes that strategic monitoring is supported by two types of processes (i.e., retrieval mode and target checking). The RM + TC model proposes that when an individual forms a delayed intention, s/he engages in a prospective memory retrieval mode, which is a cognitive state of readiness to encounter the prospective cue. The retrieval mode process would be engaged when in a relevant context until the intention is realized. In addition to retrieval mode, the individual would also engage in target checking (checking the environment for prospective cues) in contexts in which an individual anticipates encountering the prospective cue.

To appreciate the interplay between retrieval mode and target checking, one can consider the example of purchasing a gallon of milk on the way home from work. When one begins the drive home from work, retrieval mode would be engaged to prepare the neural system to carry out target checking. As you pass by various stores, target-checking would be performed to correctly reject items similar to the target (hardware, bookstore) and accept the target (grocery store). In the RM + TC theory, the combination of retrieval mode and target checking support strategic monitoring and allow for successful prospective remembering.

Guynn (2003) tested this model in an experiment in which participants completed control and experimental trials that were presented in blocked or alternating format. In the No-PM condition individuals completed reaction time and short-term memory tasks. During the PM condition the participants completed the reaction time, the short-term memory task, and an additional prospective memory task (i.e., making a key press in response to a fruit word). In the blocked condition, participants completed 24 consecutive control trials and 24 consecutive experimental trials. In contrast, the alternating condition involved completing intermixed blocks of the control and experimental trials. Guynn (2003) hypothesized that retrieval mode should be difficult to turn on and off on a trial-by-trial basis so there should be reaction time costs related to retrieval mode present in the alternating condition but not the blocked condition. In contrast, target checking should be easy to turn on and off so it would be present in experimental but not control trials in both the blocked and alternating conditions. The results of Guynn (2003) reveal that reaction times were slower in the alternating versus block condition, which provides evidence for retrieval mode. Additionally, the reaction time for the PM condition was slower than the NoPM condition in both alternating and blocked conditions, which provides evidence for target checking.

In addition to understanding the roles of spontaneous retrieval and strategic monitoring in prospective memory, researchers have also been interested in studying the role of target checking in prospective memory. Marsh, Hicks and Watson (2002) investigated the role three subcomponents of target checking (i.e., noticing the cue, retrieving the intention from memory and coordinating a response with the task demands of the ongoing activity) by measuring reaction times on successful and failed prospective memory trials. First, the researchers were interested in determining whether participants had faster reaction times for prospective cues than ongoing stimuli. The addition of a PM task has been shown to increase reaction time for ongoing activity trials and Marsh et al. (2002) hypothesized that this difference is due to the three subcomponents of target checking. If the prospective cues are stored at a higher level of activation because of their associated intention, noticing the cue may occur rapidly. However, the two additional subcomponents of target checking (i.e., retrieving the intention and coordinating the response with the task demands) would add time to successful ongoing activity trials in PM blocks resulting in longer reaction times for PM blocks compared to ongoing activity blocks. In three experiments, Marsh et al. (2002) demonstrated that the reaction times for successfully noticed prospective cues associated with a prospective response were longer than reaction times for the ongoing activity.

A second research question considered by Marsh et al. (2002) was whether failed prospective memory trials would produce the intention superiority effect (i.e., the finding of faster reaction times for prospective cue trials). In all three of their experiments, Marsh et al. (2002) found that failed prospective memory responses were faster than reaction times for ongoing activity control trials. This is consistent with the idea that prospective intentions are stored at a higher level of activation. The final research question addressed by Marsh et al. (2002) was whether reaction time differences during prospective memory trials were due to the participant having to coordinate both the prospective response and the response for the ongoing activity. To test this idea, they had participants make manual responses to both prospective cues and ongoing stimuli in one experiment while in a second experiment, participants made oral responses to prospective stimuli and manual responses to ongoing stimuli. Marsh et al. (2002) hypothesized that if coordinating prospective and ongoing trial responses is an important component of prospective memory, there should be greater reaction time costs in the second experiment (making oral and manual responses) than in the first experiment (manual responses only). The researchers did not find evidence for this type of slowing due to coordinating the two responses. Therefore, further experiments concerning the microstructure of prospective memory are necessary to elucidate the underlying components of target checking.

VI. Neurophysiology of Prospective Memory

Complementing the findings of behavioral studies, researchers have examined the neural correlates of prospective memory using a variety of techniques. One inexpensive and effective technique used to study the neural correlates of prospective memory is ERPs. Using ERPs, neurophysiological investigations of prospective memory have identified two components, the N300 and the prospective positivity, that are related to the realization of delayed intentions. In the following sections, some of the evidence from studies using ERPs is examined including the neural correlates of PM cue detection and intention retrieval, differences in the neural correlates of prospective and retrospective memory, effects of monitoring on the N300 and prospective positivity and ERPs and the RM + TC model of PM.

VII. Neural Correlates of Prospective Cue Detection

In order to realize an event-based delayed intention, one must detect a prospective cue in the environment. The N300 is associated with cue detection and typically represents a negativity over the occipital-parietal regions accompanied by a positivity over the midline frontal region between 300-400 ms after stimulus onset. The N300 is elicited when cues are defined by various characteristics of the stimuli such as letter case (West et al. , 2001), color (West & Ross-Munroe, 2002), and word identity (West, Herndon & Ross-Munroe, 2000), but to date has only been elicited by a stimulus with preexisting representation in memory.

West, Herndon and Crewsdon (2001) first reported the N300 in the partial cue PM task. Participants completed three types of trials (semantic relatedness judgment, PM lure and PM cue) in which they were simultaneously presented with two stimuli. The case of the word stimuli was varied between the three trial types and participants were required to make a prospective response only when both words were presented in uppercase font (PM cue). When participants saw two words presented in lower case font (semantic relatedness judgment trials), they were instructed to determine whether the two words were semantically related. In the PM lure condition, participants saw one word in upper case and one word in lower case and were instructed to ignore the case and make a semantic judgment. West et al. (2001) hypothesized that an ERP component dissociating PM cue and lure trials from semantic judgment trials would be an index of cue detection while an ERP component dissociating PM cue trials from PM lure trials would be an index of task set configuration.

The results of West et al. (2001) revealed that the N300 distinguished PM cue and PM lure trials from semantic judgment trials. To ensure that this modulation was not driven by the perceptual salience of the PM cue, West et al. (2001) designed a second experiment that included a PM ignore condition in which participants were required to only make semantic relatedness judgments and ignore the letter case of all words. If the N300 was independent of an intention and simply reflected the difference in the perceptual characteristics of the cues and lures, the N300 should be similar in the PM ignore and PM attend conditions. In contrast, if the N300 is specifically related to noticing a prospective cue, it should be larger in amplitude in the PM attend condition than the PM ignore condition. The results of this study revealed that the amplitude of the N300 was greater in the PM attend condition than the PM ignore condition supporting the hypothesis that the N300 is related to noticing the prospective cue.

The N300 is similar in time course to two other ERP components, the N2 and N2pc. Both the N2 and N2pc are associated with target selection during visual search and working memory tasks. The N2pc is an enhancement of the N2 component that is observed between 200-300 ms after stimulus onset over the occipital parietal region of the scalp contralateral to the visual field in which a target is presented (Luck & Hillyard, 1994). Because the N2pc has been implicated in working memory cue detection, which may share a similar mechanism with prospective cue detection, it is possible that the N2pc and the N300 are associated with the same neural mechanisms. West and Wymbs (2004) directly compared the ERPs for target and cue detection by embedding a prospective memory component in a target detection task and found that targets and prospective cues both elicited a N2pc supporting the idea that target selection in working memory and prospective memory tasks share a common neural mechanism. Additionally, West and Wymbs (2004) identified a significant effect associated with the N300 that distinguished the ERPs elicited by prospective cue trials from those elicited by target-present and target-absent trials indicating that the N300 may be uniquely related to prospective memory trials.

VIII. Neural Correlates of Intention Retrieval

Retrieving an intention from memory is an important component of prospective remembering. The prospective positivity has been associated with the retrieval of delayed intentions from memory. The prospective positivity is typically observed as a positivity over the central, parietal and occipital regions between 400-1200 ms after stimulus onset. West et al. (2001) discovered this component in a study using the partial cue paradigm mentioned in the previous section. In West et al. (2001), PM cue trials were assumed to be associated with cue detection (noticing) and retrieval of intentions (search). Using the partial cue design, an index of searching could be obtained by comparing PM cue trials (noticing and search) to PM lure (noticing) and semantic judgment trials. The results from West et al. (2001) revealed that the prospective positivity distinguished PM cue trials from PM lure and semantic judgment trials, consistent with the idea that this component of the ERPs is associated with the retrieval of a delayed intention from memory.

The time course of the prospective positivity is also similar to that of the P3, which is elicited during oddball tasks. The P3 reflects a positivity over the central-parietal and parietal region of the scalp between 300-400ms after stimulus onset and persisting to 600-800ms after stimulus onset. One major commonality between the P3 and the prospective positivity is that both are elicited during tasks that require participants to detect the occurrence of a low probability target. Despite this similarity, several studies provide evidence that the prospective positivity and the P3 reflect unique neural processes (West et al., 2003; West & Wymbs, 2004; West, Bowry & Krompinger, 2006). The first study to compare the neural processes underlying the prospective positivity and the P3, West et al. (2003), found that perceptual salience of a target modulated the amplitude of the P3 but not the prospective positivity. Additionally, the number of prospective cues modulated the prospective positivity but not the P3. West and Wymbs (2004) replicated these results by finding two significant effects that distinguish the P3 from the prospective positivity. Finally, West et al. (2006) found that the working memory load modulated the amplitude of the P3 but did not influence the amplitude of the prospective positivity. These studies provide evidence that the prospective positivity and the P3 reflect distinct neural processes.

In addition to similarities with the P3, the prospective positivity also shares similar features with the parietal old-new effect, which reflects a positivity over the parietal region between 300-800 ms after stimulus onset (Paller & Kutas, 1992). The parietal old-new effect is greater in amplitude for old items than new items in recognition memory tests and typically is greater in amplitude over the left hemisphere (Paller & Kutas, 1992). Due to the similarities between the parietal old-new effect and the prospective positivity, West and Krompinger (2005) compared the neural correlates of prospective and retrospective memory in recognition and cued-recall paradigms. The results of West and Krompinger (2005) revealed that the parietal old-new effect was elicited by both recognition hits and PM hits relative to ongoing activity trials. However, the prospective positivity emerged later than the parietal old-new effect and distinguished PM hits from recognition hits and PM control trials. The results from West and Krompinger (2005) demonstrate that while the parietal old-new effect contributes to the early portion of the prospective positivity, the prospective positivity represents a unique component of the ERPs.

Evidence examined in the previous two paragraphs indicates that the prospective positivity can be distinguished from the P3 and the parietal old-new effect, but relatively little progress has been made into identifying the cognitive processes that underlie the prospective positivity. Bisiacchi, Schiff, Ciccola and Kliegel (2009) examined the possibility that the prospective positivity is involved in task switching. Specifically, Bisiacchi et al. (2009) hypothesized that the prospective positivity is associated with the ability to switch from the ongoing activity to the prospective memory component of the task. The ongoing activity for this experiment was a letter comparison task. There were two conditions: control and task-switching. For the control condition, participants made prospective responses after completing the ongoing activity. In the task-switching condition, participants made the prospective response when encountering a prospective cue and were instructed to ignore the ongoing activity task and response. The interesting finding from this study was that the prospective positivity differentiated PM cues in the switch condition from those in the control condition. These findings indicate that the prospective positivity is associated with the neurocognitive processes that allow an individual to switch from an ongoing activity to a prospective activity.

IX. Differences in the Neural Correlates of Prospective and Retrospective Memory

Prospective memory involves both the detection of a cue and the retrieval of an intention from memory. Therefore, it is possible that retrospective and prospective memory share a common neural mechanism. West and Krompinger (2005) investigated the neural correlates of prospective and retrospective memory. In order to effectively compare prospective and retrospective memory, the experimental design involved encoding conditions, stimulus materials and response demands that were closely matched for the two forms of memory.

In West and Krompinger (2005), participants studied two words (i.e., one for a prospective memory test and one for a later recognition test) in each block of trials. After completing the encoding stage, participants began the ongoing activity phase of making semantic relatedness judgments about word pairs. The participants were told to make a prospective response when the previously encoded prospective cue appeared as one of the words. The final phase of the experiment was the recognition phase in which participants made one forced-choice judgment indicating which of two words had been studied during the encoding phase. If similar processes underlying prospective and retrospective memory, one would expect an effect that would distinguish recognition hits and prospective cue hits from ongoing activity trials. If the prospective positivity is unique to prospective memory, it should be associated with an effect that distinguishes prospective hits from recognition hits.

The results from West and Krompinger (2005) revealed two significant effects. The first effect distinguished recognition hits and prospective hits from ongoing trials indicating that there are some similar neural processes underlying prospective and retrospective memory. The second effect differentiated prospective hits from recognition hits and prospective memory control trials and indicates that there are some neural processes that are unique to prospective memory.

X. Effects of Monitoring on the N300 and Prospective Positivity

The PAM theory of prospective memory holds that strategic monitoring is crucial for the successful realization of an intention (Smith, 2003). Therefore, one prediction that can be made from the PAM theory is that strategic monitoring should influence components of the ERP related to prospective memory. West (2007) tested this hypothesis in a continuous recognition task in which participants indicated by a key press whether or not a stimulus had been presented in the current block. In the design, participants completed 60 blocks of trials with 31 trials in each block. In the first and last 10 trials of each block, the stimuli were presented in gray font, and in the middle 10 trials the stimuli were presented in green font. At the beginning of each trial, participants encoded a prospective cue and were instructed to make a prospective response if the cue was presented in green font but an ongoing activity response if the cue was presented in gray font. West (2007) predicted that the participants would engage in strategic monitoring during the middle 10 trials in which the prospective intention was relevant but would not engage in strategic monitoring during the first and last 10 trials of the block.

If the N300 and prospective positivity are sensitive to strategic monitoring, then these components of the ERPs should be limited to prospective cues in the middle 10 trials of an experimental block. The results from West (2007) revealed that the N300 and the prospective positivity were both elicited during prospective hit trials but not prospective misses or the first or last 10 trials in a block. These results indicate that the N300 and prospective positivity may be dependent on strategic monitoring.

XI. ERPs and the RM+TC model of Strategic Monitoring

Guynn's (2003) RM + TC model proposes that strategic monitoring is supported by two types of processes (i.e., retrieval mode and target checking). To date, there is little direct evidence of retrieval mode and no evidence of target checking in the ERP literature. Previous ERP studies of prospective memory have focused on characterizing the N300 and prospective positivity (West, Herndon & Crewsdon, 2001; West & Wymbs, 2004: Bisiacchi et al., 2009) or examining the relationship between prospective memory and aging (West & Bowry, 2005), retrospective memory (West & Bowry, 2005), strategic monitoring (West, 2007) and/or working memory (West & Bowry, 2005). Due to the nature of the experimental questions, past studies have not designed tasks that allow for a clear distinction between the neural correlates of retrieval mode/target checking and strategic monitoring.

XII. Current Experiments

The three experiments included in this dissertation were designed to fill a void in the literature by identifying the neural correlates of target checking in three experiments using ERPs. The extant literature examining the neural correlates of strategic monitoring is limited by experimental design. It is impossible to distinguish between modulations of the ERPs related to retrieval mode and those related to target checking. The current experiments incorporate a recently developed extension of the lexical decision task as applied in the PM literature to isolate the neural correlates of target checking. Because strategic monitoring has been shown to be important for prospective memory (Smith, 2003), it is important to characterize the neural underpinnings of strategic monitoring to better understand prospective memory failures.

Cohen et al. (2009) describe a paradigm that enabled the investigator to distinguish between retrieval mode and target checking. The between-subjects experimental design involved two blocks of trials. The first block of trials was a control block in which participants completed the ongoing activity of a lexical decision task. In the second block of trials, participants completed an embedded PM task with either word cues or nonword cues. Cohen et al. (2009) hypothesized that the ongoing trials in the prospective memory block would have slower reaction times than the control block due to the retrieval mode component of strategic monitoring. Participants would engage retrieval mode to prepare for the occurrence of a prospective cue. Further, Cohen et al. (2009) hypothesized that target checking would be engaged in the prospective block of trials. Target checking would be observed as slowing in reaction times for nonword or word ongoing trials for the nonword or word prospective memory groups, respectively. The results from Cohen et al. (2009) provided evidence for both retrieval mode and target checking. First, the reaction times were slower for the prospective block compared with the control block, which Cohen et al. (2009) attributed to retrieval mode. Second, the reaction times for ongoing nonword trials in the second prospective block were slower than ongoing word trials for the nonword prospective group. Similarly, reaction times were slower for ongoing word trials than ongoing nonword trials in the second prospective block for the word prospective group.

The behavioral paradigm developed by Cohen et al. (2009) provides a way to study both retrieval mode and target checking. Therefore, this paradigm was implemented in the

ERP investigation of the neural correlates of strategic monitoring described in this dissertation. Experiment 1 was designed to replicate the behavioral findings of Cohen et al. (2009) in a within-subjects design and examine the neural correlates of target checking. Four blocks of trials were used in Experiment 1: $Control_1$, PM_w, PM_{nw}, $Control_2$. There were two control blocks of trials ($Control_1$, $Control_2$) presented as the first and last block in the experiment. These control blocks accounted for practice effects during the ongoing lexical decision task. Participants also completed two prospective memory blocks, one containing word prospective cues (PM_w) and the other containing nonword prospective cues (PM_{nw}). These blocks were counterbalanced across participants such that half completed the PM_w block before the PM_{nw} block. The ERP data revealed two ERP components that were associated with target checking: the posterior negativity and the late positive component.

Experiment 2 was designed to examine the nature of the difference in recruitment of the posterior negativity for word and nonword PM cues. Because word and nonword stimuli have different lexical and semantic representations, the differential recruitment of the posterior negativity found in Experiment 1 may be due to the stability of the existing representations of words. If the posterior negativity is associated with an attentional filter that utilizes lexical or semantic representations to facilitate the processing of PM relevant information, the neural processes related to the posterior negativity would be differentially recruited for words and nonwords. To examine this possibility, the “wordiness” of nonword stimuli in Experiment 2 was varied using orthographic neighbor nonwords (i.e. plip) in addition to letter string nonwords (i.e. ornb). The results of Experiment 2 provide evidence that the posterior negativity is associated with an attentional filter that differentiates PM relevant stimuli based on existing representations of stimuli. However, it appears that delayed intentions can be successful retrieved without this attentional filter as the posterior negativity was not present for orthographic neighbor nonwords.

Experiment 3 was designed to examine the nature of the difference in recruitment of the LPC for words and nonwords. The LPC was hypothesized to reflect memory retrieval processes. In Experiment 1, the LPC was recruited earlier for words (600-800ms) than for nonwords (800-100ms), which may reflect an increased difficulty in representing nonword stimuli in memory. To examine this hypothesis, the number of prospective cues was varied between blocks of trials in Experiment 3 to examine whether the differences in engagement of the LPC for words and nonwords were due to late retrieval processes. The results of Experiment 3 indicate that retrieval processes were responsible for this difference recruitment of the LPC as this component of the ERPs distinguished the six prospective cue condition from the two prospective cue condition.

CHAPTER 2. EXPERIMENT 1

Introduction

The purpose of Experiment 1 was to identify the neural correlates of item checking in prospective memory. In this experiment, participants completed a lexical decision task as the ongoing activity where they indicated whether or not a letter string was a word or a nonword. Each participant completed four blocks of trials. In the first and fourth block of trials, participants completed the ongoing activity without a prospective memory component. For the second and third blocks of trials, participants completed the ongoing lexical decision task and were instructed to make a prospective response when the letter string was a prospective memory cue. To ensure that participants learned the critical items, they completed two recall and two recognition tests prior to beginning the prospective memory blocks. In one prospective block, prospective cues were nonwords and in the other prospective block prospective cues were words. The presentation of the prospective blocks was counterbalanced across participants such that half of the participants completed the nonword prospective cue block before the word prospective cue block.

For the behavioral data, slower response times for the prospective memory blocks than the no prospective memory blocks would provide evidence of strategic monitoring. Evidence of target checking would be slower reaction times for the nonwords in the nonword prospective cue block than the word prospective cue block, and slower reaction times for words in the word prospective cue block than the nonword prospective cue block. Physiological evidence for target checking would be present after the onset of the stimulus as participants should be engaging neural processing for target checking in response to the onset of a potential prospective cue.

Method

Participants

Thirty-two Iowa State University students (13 male, 1 left-handed, M=19.7 years, range = 18-28 years) participated in the experiment in exchange for course credit. Informed consent was obtained at the beginning of the study. Data for eight participants were excluded from the analyses: three participants were excluded due to the failure to make prospective memory responses, four were excluded due to excessive movement artifact in the EEG data, and one participant was excluded as a result of equipment failure.

Materials

All stimuli were presented on a black background in uppercase gray Arial 14-point font and were vertically and horizontally centered in the display. The stimuli were presented on a 17-inch monitor with 1280 x 1024 pixel resolution at a distance of 100cm. The task was programmed using the E-Prime 1.2 software (Psychology Software Tools, Pittsburgh, PA). Participants completed the Edinburgh handedness inventory (Oldfield, 1971) prior to completion of the task.

Stimuli

Lexical decision stimuli: The stimuli consisted of 175 words and 175 nonwords and each stimulus was shown twice during the experiment for a total of 700 stimuli. The words were chosen from the English Lexicon Project database (ELP; Balota et al., 2007), the average frequency was M=138 (Kucera & Francis, 1967) and the average wordlength was M=5.5. The nonwords were created by moving the first syllable of the words to the end of the word (Smith, 2003). The words and nonwords were divided into four word lists to create three lists with 100 unique stimuli and one list with 50 unique stimuli. One word list was presented in each block and the order of presentation for the first three word lists was counterbalanced across participants.

Prospective memory cues: There were five prospective memory cue words (blue, girls, decided, member and husband) and five prospective memory nonwords (hangesc, umevol, lowbe, eetm, and eeksw). Ten words and ten nonwords from each wordlist were selected and removed from the list when the list was in a prospective memory block. Five of those items were replaced by the prospective memory cues, and the other five items were controls for the prospective memory cues that matched the word and nonword cues for length and the word cues for frequency according to Kucera and Francis (1967) norms (control words: moral, boys, neither, record and student; control nonwords: lymere, encesci, orcol, airh and singu).

Design and Procedure

The task design was a 2 (prospective load: PM or NoPM) x 2 (PM cue type: word, nonword) factorial. The 700 trials were divided into three blocks of 200 trials and one block of 100 trials. The presentation of the three 200 stimulus word lists was counterbalanced across participants for the first three blocks and the final block contained the same word lists for all participants (see Appendix A). The first block ($Control_1$) was always a NoPM block followed by two PM blocks followed by a final NoPM block ($Control_2$). The two PM blocks were counterbalanced across participants, half of the participants completed the PM word cues block (PM_w) first and then the PM nonwords cues block (PM_{nw}). This order was reversed for the remaining subjects. Figure 2.1 illustrates the counterbalancing for block and word list order.

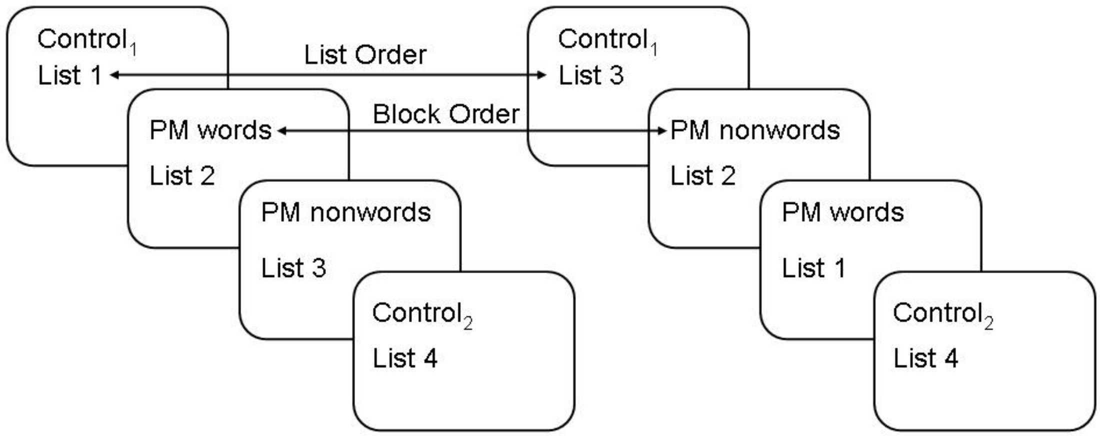

Figure 2.1. Counterbalancing for block and word list order.

The ongoing task for the experiment was a lexical decision task. The stimuli were presented in gray uppercase letters on a black background and displayed until participants made their response. Participants were instructed to press the “n” key if the letter string was a word and the “m” key if the letter string was a nonword. Before the start of the PM blocks, individuals were shown the prospective cues and given time to learn the cues. They were then given two recognition (see Appendix B) and two recall tests to ensure that they had learned the prospective cues and were told they had the additional task of pressing the “v” key after making their lexical decision response when they encountered the prospective cues in the experiment. The prospective cues were presented on trials 20, 40, 60, 80, 100, 120, 140, 160, 180, 200. There was a surprise recognition test (see Appendix G) of the PM cues at the end of the experiment and every participant correctly identified the prospective cues.

EEG Recording and Analysis

The electroencephalogram (EEG, bandpass .02–150 Hz, digitized at 500 Hz, gain 1,000, 16-bit A/D conversion) was recorded from an array of 68 tin electrodes sewn into an Electro-cap or affixed to the skin with an adhesive patch that was interfaced to a DBPA-1

(Sensorium Inc., Charlotte, VT). Vertical and horizontal eye movements were recorded from four electrodes placed below or beside the eyes. During recording, all electrodes were referenced to electrode Cz. For data analysis, the electrodes were referenced to an average reference (Picton et al., 2000). A 0.1- to 8-Hz zero-phase-shift bandpass filter was applied to the EEG data before averaging. Ocular artifacts associated with blinks were corrected using the EMSE software (Source Signal Imaging, San Diego). Trials contaminated by other artifacts (peak-to-peak deflections greater than 100 μV) were rejected before averaging. ERP epochs included data for correct responses where RT was less than 5,000 ms and excluded data from the initial trial in each block and the three trials before and after prospective cues. The ERP epoch included -200 to 1200 ms of activity around the onset of the stimuli. The electrodes chosen for measurements of the N300 and prospective positivity were those used in studies reporting these ERPs. Electrodes chosen for measurements of the remaining three ERPs (posterior negativity, frontal positivity and late prospective complex) were based on the theoretical ideas of where ERPs reflecting target checking would be present.

Results

Behavioral Data

<u>PM Cue Trials</u>

Accuracy for prospective memory trials was similar when prospective cues were words, *M*=0.93, SD=0.06, and when prospective cues were nonwords, *M*=0.94, SD=0.09, $F(1,23)=0.24$, $p=0.63$, $\eta_p^2=0.01$. Reaction time for prospective memory word cues trials, *M*=938, SD= 209, was significantly slower than reaction time for ongoing activity word trials, *M*=843, SD=183, $F(1,23)=16.69$, $p<0.001$, $\eta_p^2=0.42$. Additionally, the reaction times for prospective memory nonword cue trials, *M*= 1280, SD=380, were significantly slower than reaction times for ongoing nonword trials, *M*=819, SD=246, $F(1,23)=10.20$, $p=0.004$, $\eta_p^2 = 0.31$. These reaction time findings are consistent with previous prospective memory research (Marsh et al., 2006), which typically finds that reaction times are slower for prospective memory trials than ongoing trials.

Ongoing Activity Trials

Two analyses were performed on the data from the ongoing activity trials. The first analysis was modeled after studies examining the task interference effect (Marsh et al., 2003; Smith, 2003). This analysis reflected a 2 (word type: word, nonword) by 3 (block: $Control_1$, PM_w, PM_{nw}) ANOVA. The standard method makes the assumption that performance on the lexical decision task does not change over time. Based on the reaction time data from blocks $Control_1$ and $Control_2$ (Table 2.2) this seems unreasonable. In the second "modified" analysis, the average performance of $Control_1$ and $Control_2$ were compared with the PM_w and PM_{nw} blocks in a 2 (word type: word, nonword) by 3 (block: $Control_{12}$, PM_w, PM_{nw}) ANOVA. The modified analysis is designed to account for practice effects that may occur in a lexical decision task. Several trials were excluded from the analysis of ongoing trials: (a) the first two trials in each block; (b) PM cue trials; (c) the three trials proceeding and following PM trials; (d) trials where RTs were greater than 5000 ms; and (e) trials reflecting incorrect lexical decisions.

Standard Analysis. For the response accuracy data, the main effect of block was not significant, $F(2,46)=1.65$, $p=0.20$, $\eta_p^2=0.07$, indicating that accuracy was similar across the three blocks (Table 2.1). The main effect of word type was significant, $F(1, 23)=10.89$, $p=0.003$, $\eta_p^2=0.32$, indicating that participants were more accurate for word trials. Additionally, the 2-way interaction was significant, $F(2, 46)=21.12$, $p<0.001$, $\eta_p^2=0.48$. Post hoc analysis of the 2-way interaction revealed that participants were more accurate for word trials in the Control_1 block, $F(1, 23)=17.65$, $p<0.001$, $\eta_p^2=0.43$, and the PM_{nw} block, $F(1, 23)=17.19$, $p<0.001$, $\eta_p^2=0.43$, than the Control_2 block but there was no significant difference in accuracy between words and nonwords in the PM_w block, $F(1, 23)=1.79$, $p=0.20$, $\eta_p^2=0.07$.

The analysis of the reaction time data revealed significant main effects of block, $F(2, 46)=12.04$, $p<0.001$, $\eta_p^2=0.34$, and word type, $F(1, 23)=17.66$, $p<0.001$, $\eta_p^2=0.43$. The 2-way interaction was also significant, $F(2, 46)=21.67$, $p<0.001$, $\eta_p^2=0.49$. A priori analysis of the interaction revealed that word trials in the PM_w block were significantly slower than word trials in the Control_1 block, $F(1,23)=29.39$, $p<0.001$, $\eta_p^2=0.56$, providing evidence of target checking in the PM_w block . There was a significant difference between word reaction times when the words were presented in block Control_1 and PM_{nw}, $F(1,23)=9.23$, $p=0.01$, $\eta_p^2=0.29$, revealing retrieval mode for the PM_{nw} block. Reaction times for PM_{nw} nonwords were slower than Control_1 nonwords, $F(1,23)=12.72$, $p=0.002$, $\eta_p^2=0.36$, revealing target checking for the PM_{nw} block. There was no significant difference between nonword reaction times when the nonwords were presented in Control_1 and PM_w, $F(1,23)=2.27$, $p=0.15$, $\eta_p^2=0.09$, indicating that retrieval mode was not observed for block PM_w.

Table 2.1. Accuracy for word and nonwords during ongoing trials.

		Control_1	PM_w	PM_{nw}	Control_2	Control_{12}
Words	M	0.98	0.96	0.98	0.97	0.98
	SD	0.02	0.02	0.02	0.03	0.02
Nonwords	M	0.94	0.97	0.94	0.92	0.93
	SD	0.05	0.03	0.05	0.06	0.05

Table 2.2. Reaction Time for words and nonwords during ongoing trials.

		$Control_1$	PM_w	PM_{nw}	$Control_2$	$Control_{12}$
Words	M	723	844	819	709	716
	SD	162	183	246	233	178
Nonwords	M	890	829	1108	758	824
	SD	296	175	367	156	215

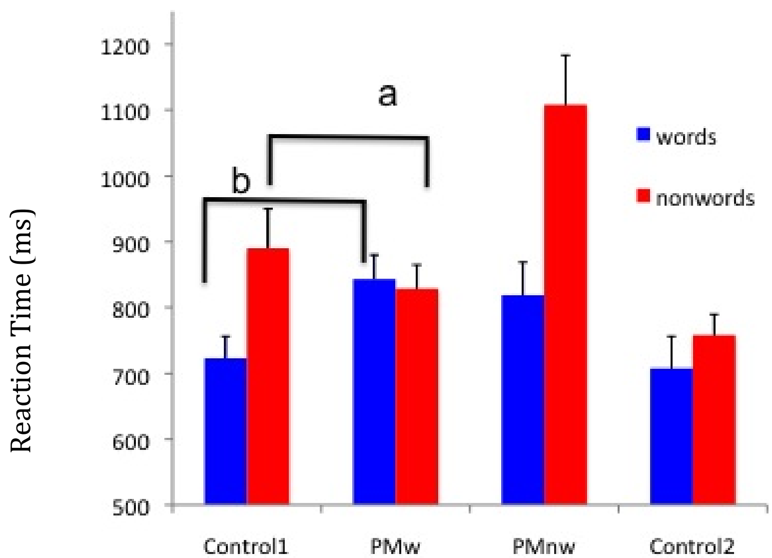

Figure 2.2. Reaction times for words and nonwords in Experiment 1. (“a” denotes retrieval mode and “b” denotes target checking).

Modified Analysis. For the analysis of accuracy, the main effects of block, $F(2,46)=6.24$, $p=0.004$, $\eta_p^2=0.21$, and word type, $F(1,23)=12.84$, $p=0.002$, $\eta_p^2=0.36$, and the interaction, $F(2,46)=20.27$, $p<0.001$, $\eta_p^2=0.47$, were significant. Post hoc analysis of the interaction revealed that participants were more accurate for word trials than nonword trials in the $Control_{12}$ block, $F(1,23)=21.14$, $p<0.001$, $\eta_p^2=0.48$, and the PM_{nw} block, $F(1,23)=17.19$, $p<0.001$, $\eta_p^2=0.43$, but not the PM_w block, $F(1,23)=1.79$, $p=0.20$, $\eta_p^2=0.07$.

The analysis of the reaction time data revealed significant main effects of block, $F(2, 46)=21.57$, $p<0.0001$, $\eta_p^2=0.48$, and word type, $F(1, 23)=15.93$, $p=0.001$, $\eta_p^2=0.41$. The 2-way interaction was also significant, $F(2, 46)=23.11$, $p<0.001$, $\eta_p^2=0.50$. The reaction times for words were significantly slower when the words were presented in the PM_w, $F(1,23)=33.07$, $p<0.001$, $\eta_p^2=0.59$, and PM_{nw}, $F(1,23)=8.77$, $p=0.01$, $\eta_p^2=0.28$ block than the $Control_{12}$ block. There were no significant reaction time differences for words in the PM_{nw} and PM_w block, $F(1,23)=0.68$, $p=0.42$, $\eta_p^2=0.08$. The slower reaction times for words in the PM_{nw} block than the C_{12} block provide evidence for retrieval mode in the PM_w block. The slower reaction reaction times for words in the PM_w block than the C_{12} block than indicate target checking for the PM_{nw} block. Reaction time was significantly slower for nonwords when these stimuli were presented in the PM_{nw} block than the $Control_{12}$ block, $F(1,23)=28.10$, $p<0.001$, $\eta_p^2=0.55$. There were not significant differences in reaction time between nonwords in the $Control_{12}$ block and the PM_w block, $F(1,23)=0.04$, $p=0.84$, $\eta_p^2=0.00$. The nonword trials were significantly slower in the PM_{nw} block than the PM_w block. $F(1,23)=32.23$, $p<0.001$, $\eta_p^2=0.58$. The absence of significant differences in reaction time for nonwords in the C_{12} block and the PM_w block provide no evidence of retrieval mode for the PM_w block. In contrast, the slower reaction times for nonwords in the PM_{nw} block than the C_{12} block provide evidence of target checking for the PM_{nw} block.

ERP Data: Realizing an intention

<u>N300</u>

The grand-averaged ERP data portraying the N300 are presented in Figure 2.3. These data reveal that the N300 appears to be present for PM_w cues and not for PM_{nw} cues over the left hemisphere. These data were analyzed for the left hemisphere in a 4 (stimulus type: PM_w word, PM_{nw} nonword, PM_w cue, PM_{nw} cue) x 2 (electrode: PO9, O1) ANOVA. The main effect of stimulus type was significant, $F(3,69)=6.93$, $p<0.001$, $\eta_p^2=0.23$. Post hoc analysis revealed no significant differences in amplitude for the N300 between word and nonword ongoing activity trials, $F(1,23)=0.01$, $p=0.92$, $\eta_p^2=0.00$. Given this, the data were collapsed across these two types of trials for further analysis. The difference in amplitude between PM_{nw} cues and the average of ongoing activity trials was not significant, $F(1,23)=3.08$, $p=0.09$, $\eta_p^2=0.12$. The amplitude of the N300 was greater for PM_w cues, M=-0.81, than for PM_{nw} cues, M=2.16, $F(1,23)=9.61$, $p=0.01$, $\eta_p^2=0.30$. The analysis for the right hemisphere reflected a 4 (stimulus type: PM_w word, PM_{nw} nonword, PM_w cue, PM_{nw} cue) x 2 (electrode: PO10, O2) ANOVA. The results revealed no significant main effect of stimulus type, $F(1,23)=1.83$, $p=0.18$, $\eta_p^2=0.07$. These results indicate that the N300 was limited to the left hemisphere and was larger for PM_w cues than PM_{nw} cues or ongoing activity trials in the left hemisphere.

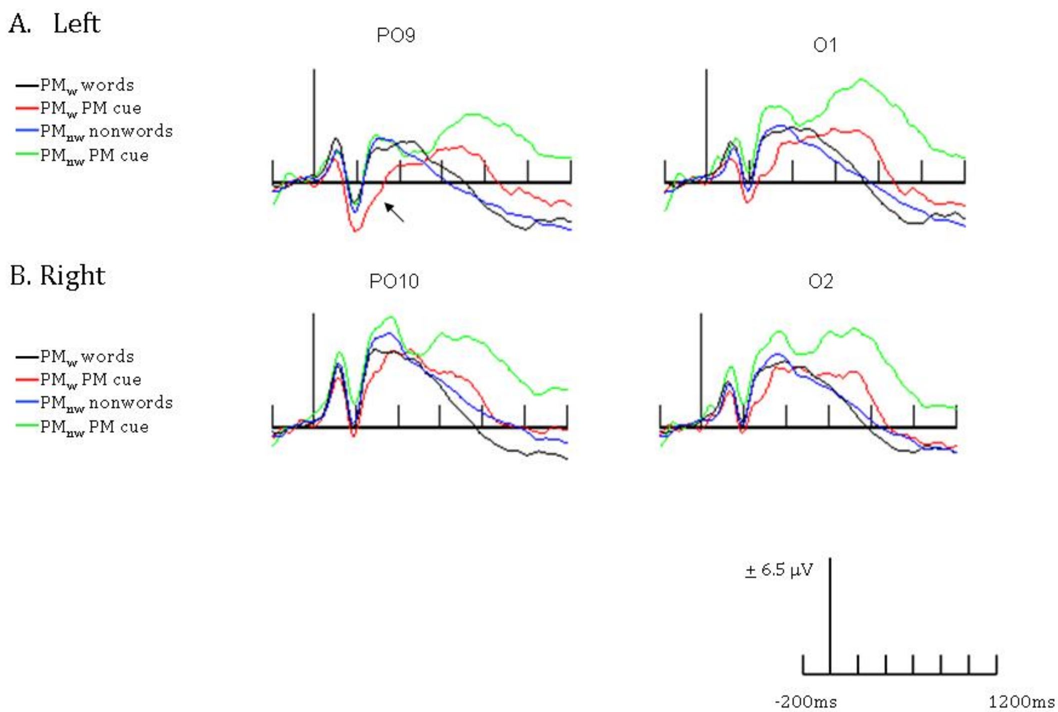

Figure 2.3. Grand-averaged ERP data for the N300.

Table 2.3. Mean voltages for the ERP data reflecting realizing an intention. The standard errors are in parentheses. (Note: PM Relevant = ongoing activity stimulus analogous to PM cue. For example, PM Relevant for the N300 in the left hemisphere PM_w block were ongoing word stimuli from the PM_w block.)

		PM cue	PM Relevant
N300 Left			
	PM_w	-0.81 (-0.91)	1.33 (0.84)
	PM_{nw}	2.16 (0.94)	1.37 (0.70)
N300 Right			
	PM_w	1.50 (1.19)	2.66 (0.89)
	PM_{nw}	3.60 (1.52)	2.84 (0.92)
Prospective Positivity 600-800ms			
	PM_w	4.44 (0.70)	2.05 (0.46)
	PM_{nw}	6.41 (0.82)	1.89 (0.50)
Prospective Positivity 800-1000ms			
	PM_w	2.35 (0.70)	-0.18 (-0.49)
	PM_{nw}	5.14 (0.89)	0.56 (0.52)
Prospective Positivity 1000-1200ms			
	PM_w	1.03 (0.69)	-0.2 (-0.34)
	PM_{nw}	3.03 (0.87)	0.01 (0.45)

Prospective Positivity

The grand-averaged ERP data portraying the prospective positivity are presented in Figure 2.4. These data reveal that the prospective positivity appears to be greater in amplitude for PM_{nw} cues than PM_w cues throughout the 600-1200ms epoch. However, the amplitude of the prospective positivity appears to be greater in amplitude for PM_w cues than ongoing activity trials for the 600-1000ms epoch while the prospective positivity appears to be greater in amplitude for PM_{nw} cues than ongoing activity trials throughout the 600-1200ms epoch. Given this, the data for the prospective positivity were analyzed in 3 epochs (600-800ms, 800-1000ms and 1000-1200ms). Analysis of each epoch reflected a 4 (stimulus type: word, nonword, PM_w cue, PM_{nw} cue) x 3 (electrode: P3, Pz, P4) design. For the analysis of the 600-800ms epoch, the main effect of stimulus type was significant, $F(3,69)=23.06$, $p<0.001$, $\eta_p^2=0.50$. Post hoc analysis of the main effect revealed no significant difference between ongoing word and nonword trials, $F(1,23)=0.41$, $p=0.53$, $\eta_p^2=0.02$, so these trials were averaged together. There were significant differences between ongoing trials and PM_{nw} cues, $F(1,23)=38.69$, $p<0.001$, $\eta_p^2=0.63$, with amplitude being greater for the PM_{nw} cue trials than the ongoing trials. There were also significant differences between ongoing trials and PM_w cue, $F(1,23)=15.96$, $p<0.001$, $\eta_p^2=0.41$, with the PM_w cue trials being greater in amplitude than the ongoing trials. Finally, the PM_{nw} cue trials were significantly greater in amplitude than the PM_w cue trials, $F(1,23)=7.62$, $p=0.01$, $\eta_p^2=0.25$. These results indicate that the prospective positivity in the early epoch (600-800ms) was greater in amplitude for PM_{nw} cue than PM_w cue trials, and greater for PM cue trials than ongoing trials.

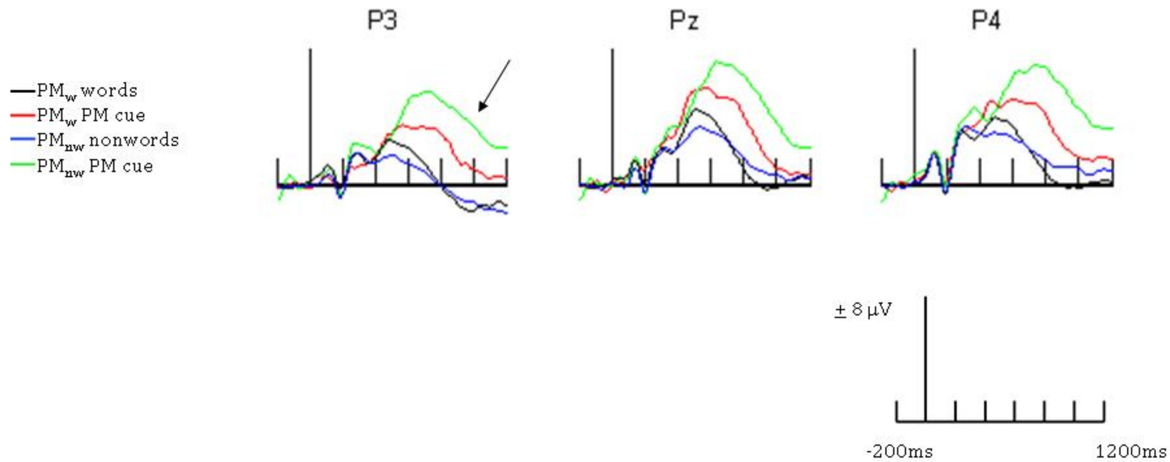

Figure 2.4. Grand-averaged ERP data for the prospective positivity.

For the 800-1000ms epoch, the main effect of stimulus type was significant, $F(3,69)=20.46$, $p<0.001$, $\eta_p^2=0.47$. Post hoc analysis revealed that the ongoing nonword trials were significantly greater in amplitude than the ongoing word trials, $F(1,23)=4.96$, $p=0.04$, $\eta_p^2=0.18$. Additionally, the PM_{nw} cues were significantly greater in amplitude than the PM_w cues, $F(1,23)=13.21$, $p<0.001$, $\eta_p^2=0.37$. These results indicate that the prospective positivity for the 800-1000ms epoch was greater in amplitude for PM_{nw} cues than PM_w cues and greater for PM cue trials than ongoing word and nonword trials. Additionally, the prospective positivity was greater for ongoing nonword trials when the prospective cue was a nonword than ongoing word trials when the prospective cue was a word.

For the 1000-1200ms epoch, the main effect of stimulus type was significant, $F(3,69)=9.27$, $p<0.001$, $\eta_p^2=0.29$. Post hoc analysis revealed no significant difference between ongoing word and nonword trials, $F(1,23)=0.41$, $p=0.53$, $\eta_p^2=0.02$, so the ongoing word and nonword trials were averaged together. There was a significant difference in amplitude between PM_{nw} cue trials and the ongoing activity trials, $F(1,23)=16.26$, $p=0.001$,

η_p^{2} =0.41. There was no significant difference in amplitude between PM word cue trials and the ongoing trials, $F(1,23)=2.56$, $p=0.11$, η_p^{2} =0.10. These results indicate that the prospective positivity in the 1000-1200ms epoch was greater in amplitude for PM_{nw} cues than PM_{w} cues, ongoing word and nonword trials. Furthermore, the prospective positivity for the PM_{nw} cues appears to peak at 1200ms indicating that participants were engaging neural processes associated with the prospective positivity for a longer period of time and at higher levels when the PM cue was a nonword than a word.

ERP Data: Target Checking

The ERP data for target checking was analyzed separately for words and nonwords. Analysis of the PM word condition included data for the $Control_{12}$ words, PM_{w} words, PM_{nw} words and PM_{w} nonwords. $Control_{12}$ words were chosen based on the findings of the modified behavioral analysis, which indicated improved performance on the ongoing task overtime. A similar analysis was performed for the nonword stimuli, which included data for the $Control_{12}$ nonwords, PM_{nw} nonwords, PM_{w} nonwords and PM_{nw} words. These analyses allowed for examination of the target checking component of strategic monitoring.

<u>Posterior negativity</u>

The grand averaged ERP portraying the posterior negativity are presented in Figure 2.5. These data reveal that when words were PM cues the posterior negativity appears to be greater in amplitude for words. In contrast, when nonwords were PM cues, the posterior negativity does not appear to be greater in amplitude for nonwords than for words. Analysis of the posterior negativity included 3 electrodes: P5, Pz, P6. For the word trials, the main effect of stimulus type was significant, $F(3,69)=4.42$, $p=0.01$, η_p^{2} =0.16. Post hoc analysis revealed no significant difference between $Control_{12}$ words, PM_{nw} words and PM_{w} nonwords,

$F(2,46)=1.25$, $p=0.30$, $\eta_p^2=0.05$, so data for these trials were averaged together for further comparison. The amplitude of the posterior negativity was significantly greater for PM_w words than the average of the other trials, $F(1,23)=8.29$, $p=0.01$, $\eta_p^2=0.27$. These results indicate that when PM cues are words the posterior negativity was limited to stimuli that were words.

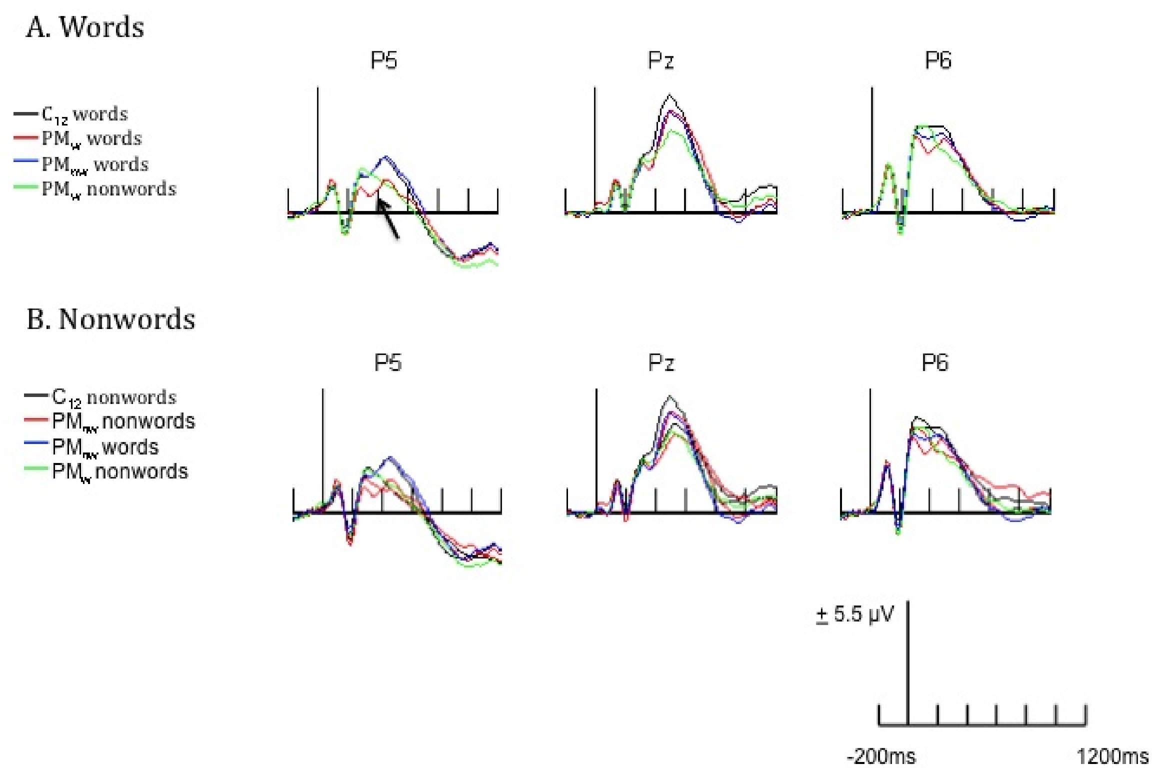

Figure 2.5. Grand-averaged ERP data for the posterior negativity.

Table 2.5. Mean voltages for ERP data reflecting target checking. The standard errors are in parentheses. (Note: Control = word or nonwords collapsed across the $Control_1$ and $Control_2$ blocks; PM relevant = ongoing activity stimulus analogous to PM cue within the stated PM block; PM Irrelevant (within) = ongoing activity stimulus not analogous to PM cue within the stated PM block; PM Irrelevant (between) = ongoing activity stimulus analogous to PM cue outside the stated PM block. For example, in the posterior negativity PM_w block line, control stimuli were $Control_{12}$ words, PM relevant stimuli were PM_w words, PM irrelevant (within) stimuli were PM_w nonwords and PM irrelevant (between) stimuli were PM_{nw} words).

		Control	PM Relevant	PM Irrelevant (within)	PM Irrelevant (between)
Posterior Negativity					
	PM_w	3.34 (0.56)	2.51 (0.64)	3.10 (0.63)	3.01 (0.66)
	PM_{nw}	3.51 (0.68)	2.77 (0.65)	3.01 (0.66)	3.10 (0.63)
Frontal Positivity					
	PM_w	-3.45 (0.52)	-1.76 (0.59)	-2.39 (0.58)	-2.59 (0.61)
	PM_{nw}	-2.82 (0.58)	-2.15 (0.57)	-2.59 (0.61)	-2.39 (0.58)
Late Positive Component 600-800 ms					
	PM_w	1.50 (0.55)	1.85 (0.58)	0.99 (0.60)	1.37 (0.53)
	PM_{nw}	1.17 (0.62)	1.69 (0.67)	1.37 (0.53)	0.99 (0.60)
Late Positive Component 800-1000ms					
	PM_w	-0.16 (0.55)	-0.54 (0.51)	-0.46 (0.5)	-0.92 (0.47)
	PM_{nw}	-0.73 (-0.52)	0.22 (0.61)	-0.92 (0.47)	-0.46 (0.5)

The analysis of the nonwords revealed a significant main effect of stimulus type, $F(3,69)=3.85$, $p=0.02$, $\eta_p^2=0.14$. Post hoc analysis revealed that the posterior negativity for PM_{nw} words and PM_w nonwords was significantly greater in amplitude than for $Control_{12}$ nonwords, $F(2,46)=4.10$, $p=0.03$, $\eta_p^2=0.15$. Additionally, the posterior negativity for PM_{nw}

nonwords was significantly greater in amplitude than for PM_{nw} words and PM_w nonwords, $F(1,23)=6.16$, $p=0.02$, $\eta_p^2=0.21$. In contrast to when PM cues were words, these results indicate that when PM cues were nonwords the posterior negativity is not limited to nonwords but is greater in amplitude for nonwords than for words.

Frontal Positivity

The grand averaged ERP portraying the frontal positivity are presented in Figure 2.6. Analysis of the frontal positivity that accompanies the posterior negativity was similar to the analysis of the posterior negativity and included 3 electrodes: F1, Fz, F2. The main effect of stimulus type was significant, $F(3,69)=16.64$, $p<0.001$, $\eta_p^2=0.42$. Post hoc analysis revealed that the amplitude of the frontal positivity for $Control_{12}$ words was significantly different from the PM_{nw} words and PM_w nonwords, $F(2,46)=12.71$, $p<0.001$, $\eta_p^2=0.36$. There was not a significant difference between PM_{nw} words and PM_w nonwords, $F(1,23)=0.84$, $p=0.37$, $\eta_p^2=0.04$. The frontal positivity for words in the PM_w was significantly greater in amplitude than for PM_{nw} words and PM_w nonwords, $F(2,46)=6.74$, $p=0.003$, $\eta_p^2=0.23$. These results indicate that when the PM cues were words the frontal positivity was greater in amplitude for words than nonwords and the frontal positivity was greater in amplitude for ongoing trial stimuli in PM blocks than no PM blocks.

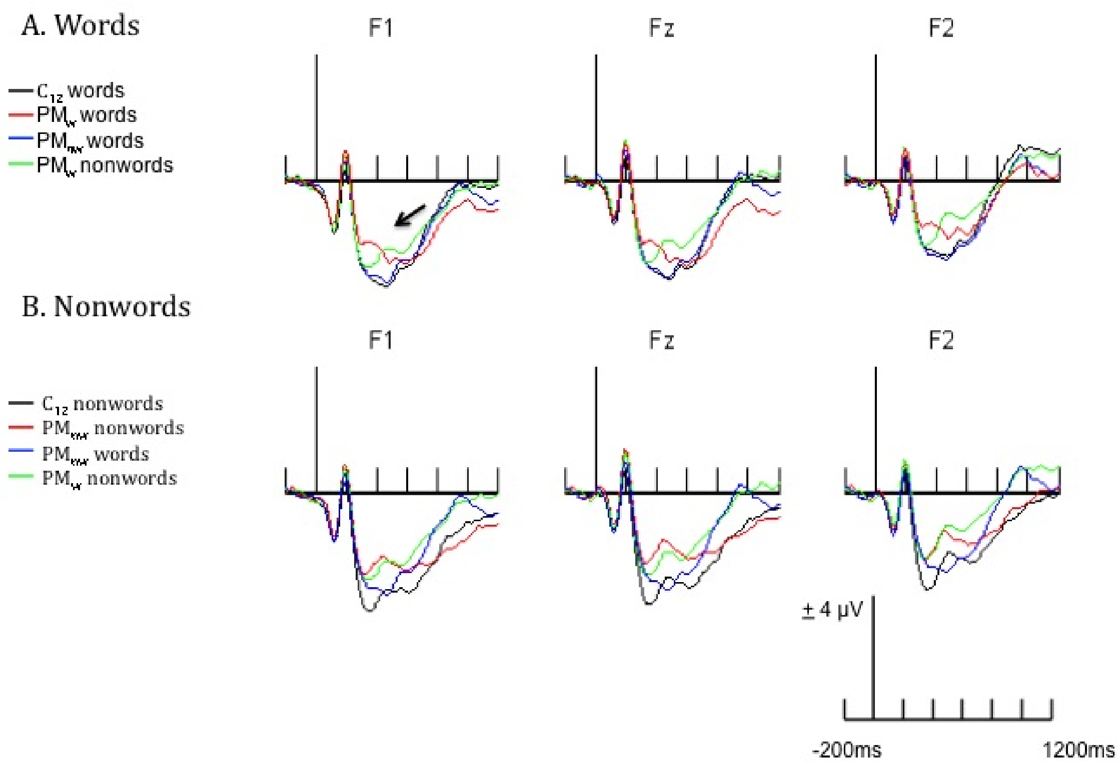

Figure 2.6. Grand-averaged ERP data for the frontal positivity.

For the nonword analysis, the main effect of stimulus type was significant, $F(3,69)=3.53$, $p=0.02$, $\eta_p^2=0.13$. Post hoc analysis revealed that the frontal positivity for PM_{nw} words and PM_w nonwords was significantly greater in amplitude than for $Control_{12}$ nonwords, $F(1,23)=6.32$, $p=0.02$, $\eta_p^2=0.22$. Additionally, the frontal positivity for PM_{nw} nonwords was not significantly greater in amplitude than for PM_{nw} words and PM_w nonwords, $F(1,23)=2.31$, $p=0.14$, $\eta_p^2=0.09$. In contrast to when PM cues are words, these results indicate that when PM cues are nonwords the frontal positivity is similar in amplitude for words and nonwords. Similar to the results from when PM cues are words, the frontal positivity is different in amplitude for ongoing trial stimuli in PM blocks than no PM blocks.

<u>Late Positive Component</u>

The grand-averaged ERP data portraying the LPC are presented in Figure 2.7. These data reveal that when words are PM cues the LPC appears to be greater in amplitude for words than nonwords in the 600-800ms epoch. In contrast, for the 800-1000ms epoch, there does not appear to be a difference in amplitude between words and nonwords. When nonwords are PM cues, there does not appear to be a difference in amplitude for the LPC between words and nonwords in the 600-800ms epoch. In contrast, for the 800-1000ms nonwords appear to be greater in amplitude than words. Given this, the data for the LPC were analyzed in 2 epochs: 600-800ms and 800-1000ms. Analysis of each epoch included 3 electrodes: P3, Pz, P4.

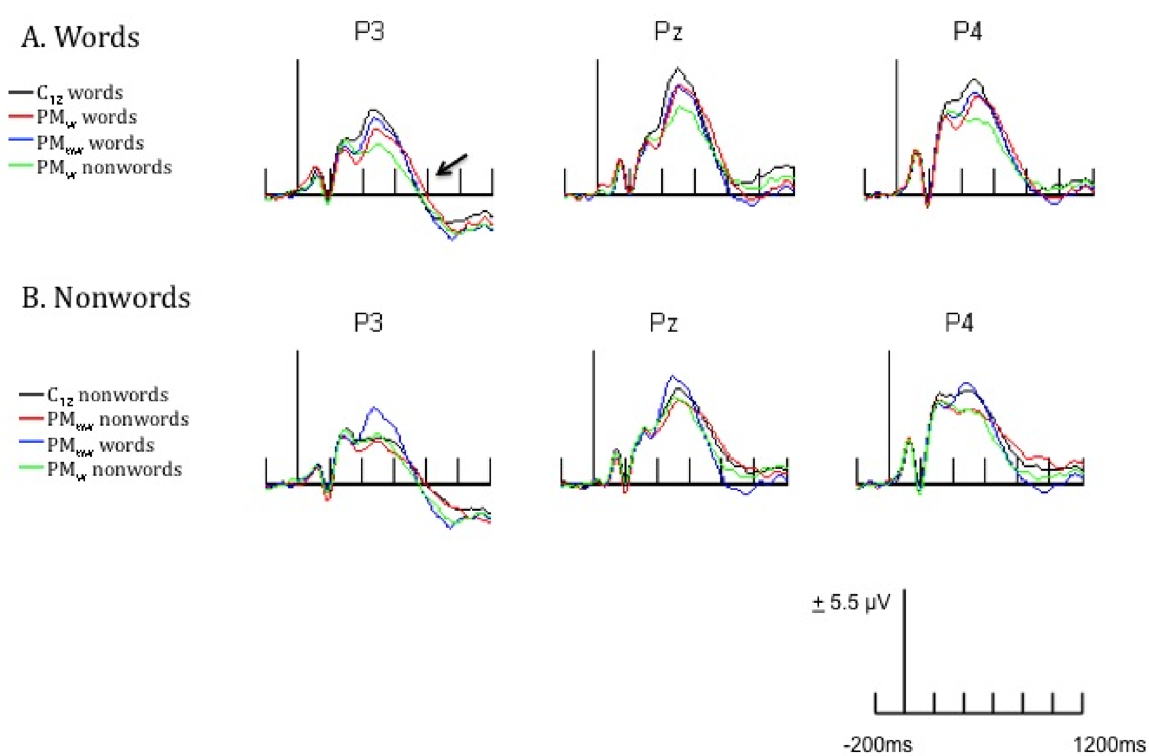

Figure 2.7. Grand averaged ERP data for the LPC.

For the analysis of the 600-800ms epoch when PM cues were words, the main effect of stimulus type was not significant, $F(3,69)=2.52$, $p=0.15$, $\eta_p^2=0.09$. However, further analysis revealed that PM_w words were significantly greater in amplitude than PM_w nonwords, $F(1,23)=8.64$, $p=0.01$, $\eta_p^2=0.27$. For the analysis of 800-1000ms epoch for words the main effect of stimulus type was not significant, $F(3,69)=1.59$, $p=0.20$, $\eta_p^2=0.07$. Post hoc analysis revealed that PM_w words were not significantly greater in amplitude than PM_w nonwords, $F(1,23)=0.07$, $p=0.79$, $\eta_p^2=0.00$. These results indicate that when the prospective cue is a word, the LPC is significantly larger in amplitude for word trials than nonword trials in the 600-800ms epoch but not 800-1000ms epoch.

For the analysis of the 600-800ms epoch when PM cues were nonwords, the main effect of stimulus type was not significant, $F(3,69)=1.32$, $p=0.28$, $\eta_p^2=0.05$. Post hoc analysis revealed no significant amplitude differences between PM_{nw} nonwords and PM_{nw} words, $F(1,23)=0.53$, $p=0.48$, $\eta_p^2=0.02$. For the analysis of the 800-1000ms epoch, the main effect of stimulus type was significant, $F(3,69)=3.06$, $p=0.04$, $\eta_p^2=0.12$. Post hoc analysis revealed that PM_{nw} nonwords were significantly greater in amplitude than PM_{nw} words, $F(1,23)=5.40$, $p=0.03$, $\eta_p^2=0.19$. There was no significant difference in amplitude between PM_{nw} words and $Control_{12}$ nonwords, $F(2,46)=0.84$, $p=0.43$, $\eta_p^2=0.04$. In contrast to when PM cues are words, these results indicate that when PM cues are nonwords, the LPC is not significantly different for words and nonwords in the 600-800ms epoch but is significantly greater in amplitude for the nonwords than words in the 800-1000ms epoch.

Discussion

The present experiment was designed to examine the neural correlates of target checking using a paradigm developed by Cohen et al. (2009). This paradigm supports the examination of target checking and retrieval mode in the behavioral data. Target checking was defined as slower reaction times for the relevant stimulus in the PM block than the control blocks. Retrieval mode was defined as slower reaction times for the irrelevant stimulus in the PM block than the C_{12} block. The behavioral data revealed target checking but not retrieval mode for the PM_w block and both target checking and retrieval mode for the PM_{nw} block. These results provide some support for Guynn's (2003) RM + TC model of strategic monitoring. Target checking was observed in both PM blocks providing evidence that target checking is important for successful PM; however, retrieval mode was only present in the PM_{nw} block indicating that, in some instances, retrieval mode may not be necessary for successful PM.

Examination of the physiological data revealed two modulations of the ERPs that have previously been associated with realizing a delayed intention: the N300 and the prospective positivity. Analysis of the N300 revealed that this component was limited to the left hemisphere and was greater in amplitude for PM_w cues than PM_{nw} cues or ongoing trials. This is consistent with previous literature reporting greater amplitude for the N300 for PM cues than ongoing activity trials (West, Herndon & Crewsdon, 2001; West & Wymbs, 2004; West & Krompinger, 2005; West, 2007). However, previous studies of the N300 report greater amplitude over the right hemisphere (West, Herndon & Crewsdon, 2001; West & Wymbs, 2004; West & Krompinger, 2005; West, 2007), while in the current experiment the N300 was greater in amplitude over the left hemisphere. This finding may be due to differential processing of words over the left hemisphere than the right hemisphere. Given that the N300 has been associated with noticing the prospective cue (West et al., 2001; West & Wymbs, 2004), these results provide evidence that the participants were able to engage neural processes associated with noticing cues that were words relative to cues that were nonwords.

In contrast to the N300, the data for the prospective positivity revealed that the amplitude of the prospective positivity was greater for PM_{nw} cues than PM_w cues and greater in amplitude for PM trials than ongoing activity trials in both the 600-800ms and 800-1000ms epochs. During the 1000-1200ms epoch, the prospective positivity continued to be greater in amplitude for the PM_{nw} cues than PM_w cues, but the PM_w cues during this epoch were not significantly greater in amplitude than ongoing activity trials. These results indicate that for PM_{nw} cues participants maintained the neural processes associated with the prospective positivity for a longer period of time than was necessary for the PM_w cues. Since the prospective positivity has been associated with post-retrieval processing (West, Herndon & Crewsdon, 2001; West & Krompinger, 2005; West, 2007) and there were no accuracy differences between prospective trials in the PM_w and PM_{nw} blocks, it is possible that participants required different processing to successfully complete the prospective task for nonwords.

Three modulations of the ERPs were associated with target checking: posterior negativity, frontal positivity and LPC. Analysis of the posterior negativity revealed that when PM cues were words, the posterior negativity was limited to words. In contrast when PM cues were nonwords, the posterior negativity was present for both words and nonwords and was greater in amplitude for nonwords than words. This relatively early difference in neural processing for word and nonword stimuli is interesting and may be related to the stable existing representations of the word stimuli. Words have both a lexical and semantic representations that nonwords in this experiment lacked. It is possible that target checking is supported by an attentional filter that facilitates the processing of PM relevant information. An attentional filter could differentiate stimuli based lexical or semantic characteristics. If the posterior negativity is associated neural processes reflecting an attentional filter, the posterior negativity should be differentially recruited for words and nonwords. Words would be captured by an attentional filter as they have lexical and semantic representations; however, the nonwords used in this experiment do not have existing representations and an attentional filter that utilizes existing representations of stimuli would not be able to capture nonword stimuli in this experiment.

Analysis of the frontal positivity that accompanied the posterior negativity revealed that when PM cues were words, the frontal positivity was greater in amplitude for words than nonwords. When PM cues were nonwords, the frontal positivity was similar in amplitude for words and nonwords but different in amplitude for ongoing trial stimuli in PM blocks than no PM blocks. The finding that the frontal positivity was greater in amplitude during PM blocks than no PM blocks indicates that neural processes were recruited to help complete the prospective task. It is possible that frontal/posterior interactions may support target checking as the neural processes associated with the frontal positivity and posterior negativity were similarly in this experiment.

The LPC was analyzed in two epochs: 600-800ms and 800-1000ms. Examination of the results revealed that when the PM cue was a word, the LPC was greater in amplitude for word trials than nonword trials during a 600-800ms epoch but not the 800-1000ms epoch. In contrast, when PM cue was a nonword, the LPC was not significantly different for words and nonwords in the 600-800ms epoch but was significantly greater for nonwords during the 800-1000ms epoch. When the PM cue was a word, participants were able to recruit neural processes associated with the LPC earlier than when the PM cue was a nonword. These findings indicate that participants engage the neural processes associated with the LPC differently when the PM cue was a word and nonword. Parietal recruitment has been associated with retrieval processes. For example, the parietal old-new effect is one modulation of the ERP across the parietal lobe that is posited to reflect retrieval processes (Rugg et al., 1998). The parietal old-new effect is greater in amplitude for deeply encoded items than shallowly encoded items and better for old items than newly presented items (Donaldson & Rugg, 1998; Rugg et al., 1998). The LPC shares some features with this parietal old-new effect in that it was greater in amplitude for words in the early epoch and for nonwords in the late epoch. It is possible that the LPC is associated with the retrieval of a delayed intention from memory. Perhaps the neural processes associated with the LPC were recruited later for nonwords because the nonwords do not have lexical and semantic representations making them difficult to retrieve from memory.

CHAPTER 3. EXPERIMENT 2

Introduction

The purpose of Experiment 2 was to examine the nature of the difference in the presence of the posterior negativity for words and nonwords obtained in Experiment 1. Participants were able to engage the neural processes associated with the posterior negativity specifically for words when the PM cue was a word. In contrast, when the PM cue was a nonword, the posterior negativity was greater in amplitude for nonword trials than word trials and greater in amplitude for word trials than control nonword trials. Why were individuals able to recruit the neural processes associated with the posterior negativity specifically for words when the PM cue was a word, but unable to engage the same neural process differentially for nonwords when the PM cue was a nonword?

Words possess both lexical and semantic representations that the nonwords used in Experiment 1 do not. A stable representation would be beneficial for the retrieval of delayed intentions if target checking operates like an attentional filter that facilitates the processing of PM relevant stimuli by differentiating PM relevant stimuli using an existing lexical or semantic representation. To test the idea of the posterior negativity being associated with an attentional filter, the “wordiness” of the nonword stimuli was varied using orthographic neighbor nonwords (i.e., plip) and letter string nonwords (i.e., ornb). The letter string nonwords do not have a lexical representation but the orthographic neighbor nonwords do have a lexical representation as they visually resemble words. If differences in recruitment of the neural processes associated with the posterior negativity were found between letter string and orthographic neighbor nonwords, then the attentional filter could differentiate stimuli based on lexical characteristics. In contrast, the orthographic neighbor nonwords would have lexical characteristics similar to words, but would not have semantic representations. Any differences in recruitment of the neural processes associated with the posterior negativity between words and orthographic neighbor nonwords would provide evidence that the attentional filter usees semantic representations to differentiate stimuli.

In Experiment 2, participants completed five blocks of trials. In the first and fifth block of trials, participants completed ongoing activity trials of a lexical decision task without a prospective memory component. In the second to fourth blocks of trials, participants completed both the ongoing activity trials and a prospective memory component (press “v” when a stimulus was a PM cue). There were three types of PM cues: words, orthographic neighbor nonwords (nonwords$_{ON}$) and letter string nonwords (nonwords$_{LS}$). If the attentional filter associated with the posterior negativity is dependent upon a semantic representation, then the posterior negativity should distinguish words from orthographic neighbor and letter string nonwords. If the attentional filter associated with the posterior negativity is dependent upon a lexical representation, then the posterior negativity should distinguish words and orthographic neighbor nonwords from letter string nonwords.

Method

Participants

Twenty-eight Iowa State University students (11 male, 1 left-handed, 1 ambidextrous, *M*=20.1 years, range=18-33 years) participated in the experiment in exchange for course credit. Informed consent was obtained at the beginning of the study. Data for six participants were excluded from the analyses: three participants were excluded due to the failure to make any prospective responses and three participants were excluded due to excessive movement artifact in the EEG data.

Materials

The materials for Experiment 2 were the same as Experiment 1.

Stimuli

The stimulus list consisted of 180 words and 180 nonwords. All of the words were chosen from the ELP database (Balota et al., 2007) and had an average frequency of *M*=138, *SD*=15.5 (Kucera & Francis, 1967) and an average wordlength of *M*=5.5, *SD*=0.9. There were two types of nonwords: letter strings and orthographic neighbors. The letter string nonwords (nonwords_{LS}) were created by moving the first syllable of a word to the end of the word. The orthographic neighbor nonwords (nonwords_{ON}) were chosen from the ELP database (Balota et al., 2007) with orthographic neighborhood size between 5-7. Neighborhood size reflects the number of words with similar orthographic and phonological characteristics and is one way to determine orthographic distinctiveness. The words and nonwords were divided into five word lists to create four lists with 80 unique stimuli and one list with 40 unique stimuli. One word list was presented in each block and the order of presentation for the first four word lists was counterbalanced across conditions. Each stimulus was presented twice in the relevant block resulting in a total of 720 trials.

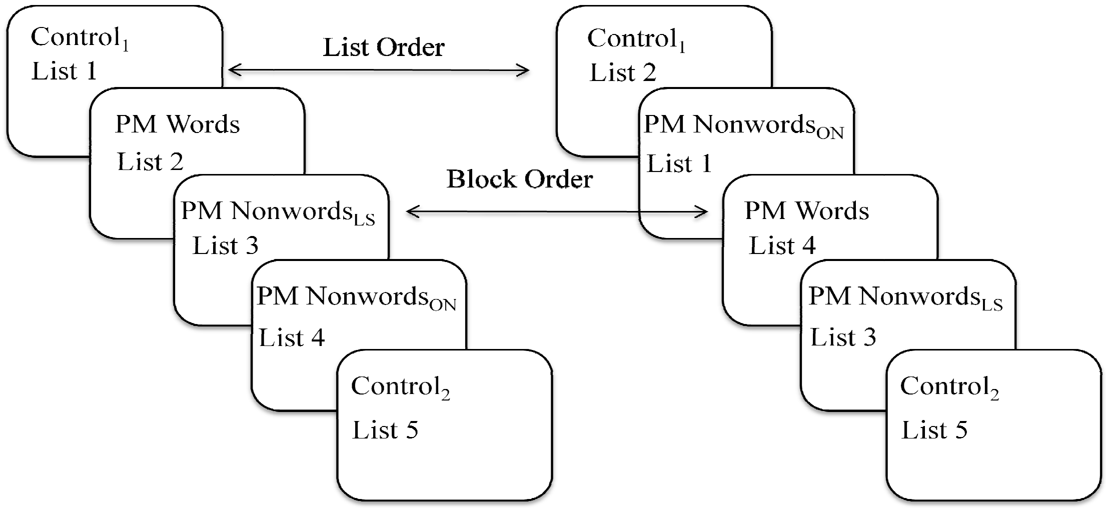

Figure 3.1. Counterbalancing for word list and block order in Experiment 2.

There were four PM cue words (blue, girls, decided, and member), four letter string PM cues (hangesc, umevol, lowbe, and eetm) and four neighbor PM cues (borm, spunt, jashed and glaying) presented during the PM blocks. Eight words, eight nonwords$_{ls}$ and eight nonwords$_{on}$ from each wordlist were selected and removed from the list when the list was used for a PM block. Four of those items were replaced by the PM cues, the other four items were controls for the PM cues that match the PM targets for word length and frequency, for the words, according to Kucera and Francis (1967) norms (control words: moral, boys, neither, and record; control nonwords$_{ls}$: lymere, encesci, orcol, and airh; control nonwords$_{on}$: wuns, bickle, vages, deaches).

Design and Procedure

The task design was a 2 (prospective load: PM or NoPM) by 3 (PM cue type: word, nonword$_{ls}$, nonword$_{on}$) factorial. The 720 trials were divided into four blocks of 160 trials and one block of 80 trials. The presentation of the four 160 stimulus lists was counterbalanced across participants for the first four blocks and the final block contained the same word list for all participants (see Appendix C). The first block was always a NoPM block ($Control_1$) followed by three PM blocks (PM_W, PM_{ON}, PM_{LS}) followed by a final NoPM block ($Control_2$). The order of the three PM blocks was counterbalanced across participants.

The ongoing task for the experiment was a lexical decision task. The stimuli were presented in gray uppercase letters on a black background and displayed until participants made a response. Participants were presented with a stimulus and asked to press the “n” key if the stimulus was a word and the “m” key if the stimulus was a nonword. Before the start of the PM blocks, individuals were shown the PM cues and given time to learn those words. They were then given two recognition and two recall tests to ensure that they had learned the PM cues (see Appendices B and D). They were told that they had the additional task of pressing the “v” key after making the lexical decision response when they encounter the PM cues in the next block. The PM cues were presented on trials 20, 40, 60, 80, 100, 120, 140, and 160. There was a surprise recognition test (see Appendix H) of the PM cues at the end of the experiment and every participant correctly recognized the prospective cues.

EEG Recording Materials and Analysis

The recording and processing of the EEG data were the same as Experiment 1. ERP epochs included data for correct responses where RT was less than 5,000 ms and excluded data from the initial trial in each block and the three trials before and after prospective cues. The ERP epoch included -200 to 1200 ms of activity around stimulus onset. Electrodes chosen for measurements of the ERPs reported in Experiment 1 (posterior negativity and late positive component) were based on the electrodes used in Experiment 1.

Results

Behavioral Data

PM cue trials

Accuracy for the PM trials was similar when PM cues were words, *M*=0.88, *SD*=0.14, nonwords$_{LS}$, *M*=0.92, *SD*=0.15, and nonwords$_{ON}$, *M*=0.91, *SD*=0.15, $F(2,46)=0.52$, $p=0.60$, $\eta_p^2=0.02$. Reaction time for PM word cues, *M*=851, *SD*=179, was significantly slower than reaction time for ongoing words, *M*=716, *SD*=101, $F(1,23)=21.40$, $p<0.001$, $\eta_p^2=0.48$; reaction time for PM nonword$_{LS}$ cues, *M*=1123, *SD*=374, was significantly slower than ongoing nonwords$_{LS}$, *M*=952, *SD*=283, $F(1,23)=18.04$, $p<0.001$, $\eta_p^2=0.44$; and reaction time for PM nonword$_{ON}$ cues, *M*=988, *SD*=199, was significantly slower than ongoing nonword$_{ON}$ trials, *M*=868, *SD*=153, $F(1,23)=10.86$, $p=0.003$, $\eta_p^2=0.32$. These reaction time differences demonstrate a cue interference effect and are similar to the findings of Experiment 1.

Ongoing Activity Trials

In Experiment 1, two analyses were performed on the behavioral data. Based on the results of Experiment 1, only the modified analysis was performed on the data for the ongoing trials in Experiment 2. Several trials were excluded from the analysis of the ongoing trials: (a) the first two trials in each block; (b) PM cue trials; (c) the three trials proceeding and following PM trials; (d) trials where reaction time was greater than 5000ms; and (e) trials reflecting incorrect lexical decisions.

The response accuracy data are presented in Table 3.1. Accuracy data was analyzed across blocks for each stimulus type to determine if there were differences in accuracy between blocks.

Word Accuracy. The accuracy analysis for words revealed a significant difference in accuracy between blocks, $F(3,69)=232.98$, $p<0.001$, $\eta_p^2=0.91$. Further analysis revealed no significant difference in reaction time between Control words, PM_{LS} words and PM_{ON} words, $F(2,46)=2.65$, $p=0.09$, $\eta_p^2=0.10$, so these trials were averaged together for further analysis. Participants were significantly less accurate for PM_W words than the average of PM_{LS} words, PM_{ON} words and Control words.

$Nonword_{LS}$ Accuracy. The accuracy analysis for $nonword_{LS}$ stimuli revealed a significant difference in accuracy between blocks, $F(2,46)=168.52$, $p<0.001$, $\eta_p^2=0.88$. Further analysis revealed no significant difference in accuracy between Control $nonword_{LS}$ and PM_W $nonword_{LS}$ stimuli, $F(1,23)=1.36$, $p=0.26$, $\eta_p^2=0.06$, so these trials were averaged together for further analysis. Participants were significantly less accurate for PM_{LS} $nonword_{LS}$ stimuli, $F(1,23)=470.83$, $p<0.001$, $\eta_p^2=0.95$, than PM_W $nonword_{LS}$ and Control $nonword_{LS}$ stimuli.

$Nonword_{ON}$ Accuracy. The accuracy analysis for $nonword_{ON}$ stimuli revealed a significant difference in accuracy between blocks, $F(2,46)=3.59$, $p=0.04$, $\eta_p^2=0.14$. Additional analysis revealed no significant difference in accuracy between Control $nonword_{ON}$ stimuli and PM_W $nonword_{ON}$ stimuli, $F(1,23)=0.12$, $p=0.72$, $\eta_p^2=0.01$, so these trials were averaged together for further analysis. Participants were significantly less accurate for PM_{ON} $nonwords_{ON}$ than Control $nonwords_{ON}$ and PM_W $nonwords_{ON}$, $F(1,23)=8.70$, $p=0.007$, $\eta_p^2=0.27$.

The reaction time data are presented in Table 3.2 and Figure 3.2. Reaction time data were analyzed by block for the presence of retrieval mode and target checking.

PM_w block. The analysis of reaction time for the PM_W block revealed no significant difference in reaction times between Control nonwords$_{LS}$ and PM_W nonwords$_{LS}$, $F(1,23)=1.34$, $p=0.26$, $\eta_p^2=0.06$. Furthermore, there was no significant difference in reaction times between Control nonwords$_{ON}$ and PM_W nonwords$_{ON}$, $F(1,23)=0.58$, $p=0.46$, $\eta_p^2=0.02$. There results provide no evidence of retrieval mode for the PM_W block. The reaction times for PM_W words were significantly slower than Control words, $F(1,23)=36.41$, $p<0.001$, $\eta_p^2=0.61$, providing evidence of target checking for the PM_W block.

PM_{LS} block. Analysis of the reaction times for the PM_{LS} block revealed slower reaction times for PM_{LS} words than Control words, $F(1,23)=24.74$, $p<0.001$, $\eta_p^2=0.52$, providing evidence of retrieval mode for the PM_{LS} block. Additionally, the reaction times for PM_{LS} nonwords$_{LS}$ were significantly slower than the reaction times for Control nonwords$_{LS}$, $F(1,23)=21.55$, $p<0.001$, $\eta_p^2=0.48$, providing evidence of target checking and retrieval mode.

PM_{ON} block. The analysis of the PM_{ON} block reaction times revealed slower reaction times for PM_{ON} words than Control words, $F(1,23)=47.44$, $p<0.001$, $\eta_p^2=0.67$, providing evidence of retrieval mode for the PM_{ON} block. There were no significant differences in reaction time between PM_{ON} nonwords$_{ON}$ and Control nonwords$_{ON}$, $F(1,23)=2.18$, $p=0.15$, $\eta_p^2=0.09$, but the effect is in the right direction.

Table 3.1 Accuracy for words and nonwords during ongoing trials. (*Note*: Nonwords_{LS} were not present in block PM_{ON} and nonwords_{ON} were not present in block PM_{LS}).

		PM_w	PM_{LS}	PM_{ON}	Control
Words	M	0.84	0.98	0.97	0.98
	SD	0.03	0.02	0.03	0.02
Nonwords_{LS}	M	0.96	0.81		0.97
	SD	0.05	0.04		0.03
Nonwords_{ON}	M	0.85		0.77	0.83
	SD	0.18		0.05	0.13

Table 3.2 Reaction time for words and nonwords during ongoing trials. (*Note*: Nonwords_{LS} were not present in block PM_{ON} and nonwords_{ON} were not present in block PM_{LS}).

		PM_w	PM_{LS}	PM_{ON}	Control
Words	M	716	680	718	625
	SD	101	91	114	68
Nonwords_{LS}	M	722	952		704
	SD	92	283		91
Nonwords_{ON}	M	812		868	827
	SD	103		153	109

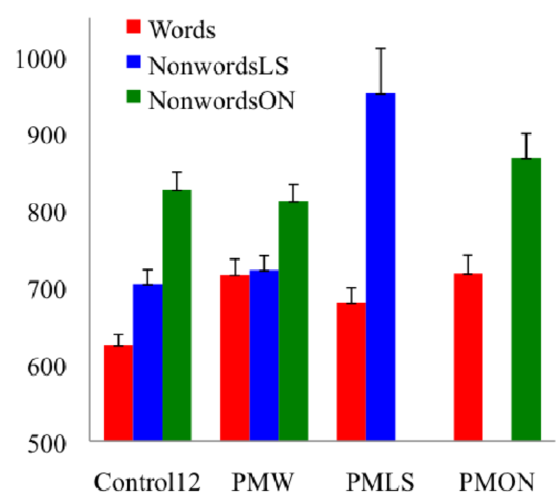

Figure 3.2 Reaction times for words and nonwords in Experiment 2. (*Note*:

Nonwords$_{LS}$ were not present in block PM$_{ON}$ and nonwords$_{ON}$ were not present in block PM$_{LS}$).

ERP Data: Target Checking

The ERP data for target checking were analyzed separately for word, nonword$_{LS}$ and nonword$_{ON}$ stimuli. Analysis of the word stimuli included data for the Control words, PM$_{W}$ words, PM$_{ON}$ words, and PM$_{LS}$ words. For nonword$_{LS}$ stimuli, the analysis included Control nonword$_{LS}$, PM$_{LS}$ nonwords$_{LS}$, and PM$_{W}$ nonword$_{LS}$. A similar analysis was performed on the nonword$_{ON}$ stimuli, which included data for the Control nonwords$_{ON}$, PM$_{ON}$ nonwords$_{ON}$, and PM$_{W}$ nonword$_{ON}$.

<u>Posterior Negativity</u>

The grand-averaged ERPs portraying the posterior negativity at three parietal electrodes are presented in Figure 3.3 and mean voltage for the ERP data is presented in Table 3.3. Visual inspection of the waveforms indicates that the posterior negativity extends from 300-500ms. The neural processes associated with the posterior negativity appear to be engaged for words from 300-500ms, nonwords$_{LS}$ from 300-400ms and not present for nonwords$_{ON}$. Given this, the posterior negativity was analyzed in two epochs (300-400ms and 400-500ms). Analyses of the posterior negativity reflected a 4 (block: Control, PM$_{W}$, PM$_{ON}$, PM$_{LS}$) x 3 (electrode: P5, Pz and P6) design.

Word trials. In the analyses of the early epoch (300-400ms), the main effect of block was significant, $F(3,63)=2.87$, $p=0.043$, $\eta_p^2=0.12$. Post hoc analysis revealed no significant differences in amplitude between PM$_{LS}$, PM$_{ON}$, and PM$_{W}$ words, $F(2,42)=0.92$, $p=0.41$, $\eta_p^2=0.04$, so data for these trials were averaged together for further comparison. The amplitude of the posterior negativity was greater for the average of PM$_{LS}$, PM$_{ON}$, and PM$_{W}$ words than the Control words, $F(1,21)=5.74$, $p=0.026$, $\eta_p^2=0.22$. Analysis of the late epoch (400-

500ms), revealed a significant main effect of block, $F(3,63)=4.17$, $p=0.009$, $\eta_p^2=0.17$. Post hoc analyses revealed no significant amplitude differences between PM_{LS}, PM_{ON}, and PM_W words, $F(2,42)=0.55$, $p=0.58$, $\eta_p^2=0.03$, so data for these trials were averaged together for further comparison. The amplitude of the posterior negativity was greater for the average of PM_{LS}, PM_{ON}, and PM_W words than the Control words, $F(1,21)=13.02$, $p=0.002$, $\eta_p^2=0.38$. These results diverge from Experiment 1 and indicate that the posterior negativity was greater in amplitude for word and nonword trials in PM blocks than control blocks in both the early (300-400ms) and late (400-500ms) epochs.

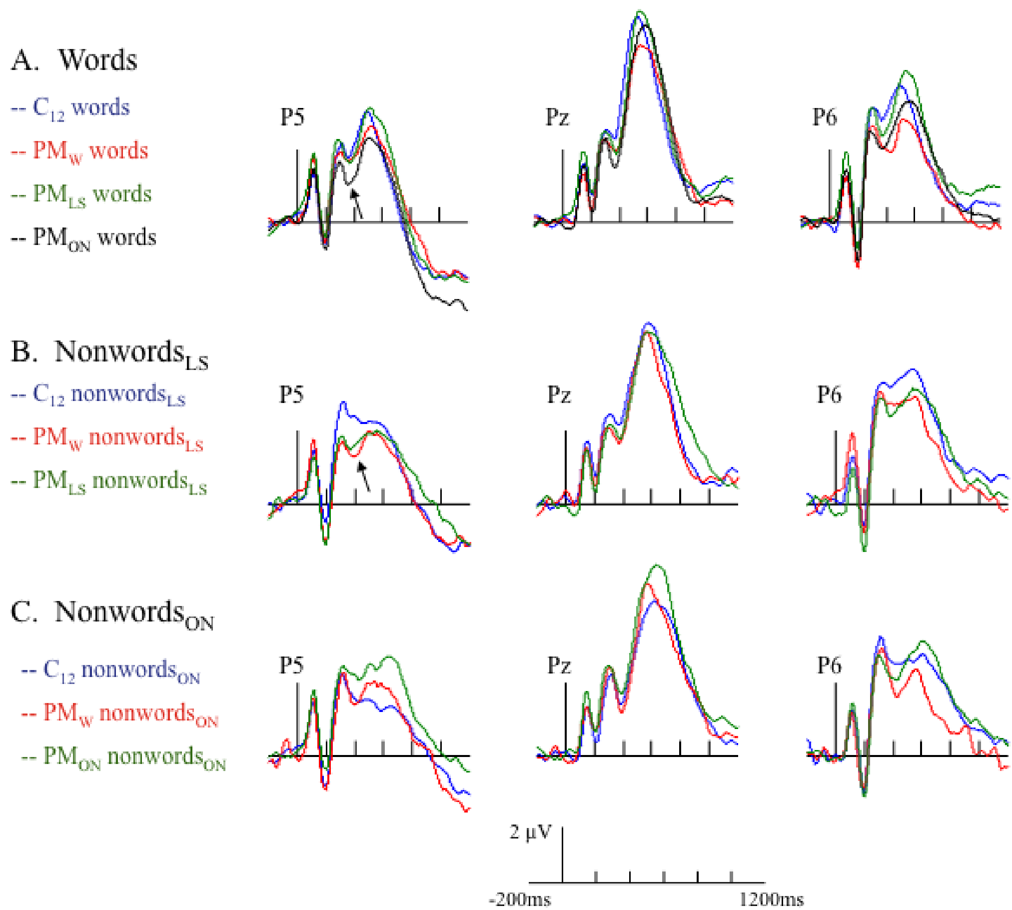

Figure 3.3. Grand-averaged ERPs portraying the posterior negativity.

Nonword$_{LS}$ trials. The analysis of the early epoch of the posterior negativity for nonword$_{LS}$ trials revealed a significant main effect of block, $F(2,42)=3.15$, $p=0.05$, $\eta_p^2=0.13$. Post hoc analyses revealed no significant difference between PM$_W$ and PM$_{LS}$ nonword$_{LS}$ stimuli, $F(1,21)=0.03$, $p=0.87$, $\eta_p^2=0.00$, so the data for these trials were averaged together for further comparison. The amplitude of the posterior negativity was greater for the average of the PM$_{LS}$ and PM$_W$ nonword$_{LS}$ trials than the Control nonword$_{LS}$ trials, $F(1,21)=7.46$, $p=0.01$, $\eta_p^2=0.26$. In the analysis of the late epoch, the main effect of block was not significant, $F(2,42)=1.75$, $p=0.19$, $\eta_p^2=0.08$. These results indicate that the neural processes associated with the posterior negativity were engaged for nonword$_{LS}$ trials in the PM$_W$ and PM$_{LS}$ blocks but not in the Control block during the early epoch. In the late epoch, the results indicate that the neural processes associated with the posterior negativity were likely not engaged for nonword$_{LS}$ trials in any block.

Table 3.3. Mean voltages for the ERP data reflecting target checking. The standard errors are in parentheses.

		Control	PM$_W$	PM$_{LS}$	PM$_{ON}$
Posterior Negativity 300-400ms					
	Words	1.86 (0.36)	1.54 (0.37)	1.44 (0.37)	1.27 (0.39)
	Nonwords$_{LS}$	2.04 (0.26)	1.38 (0.38)	1.43 (0.44)	
	Nonwords$_{ON}$	1.35 (0.42)	1.52 (0.40)		1.71 (0.39)
Posterior Negativity 400-500ms					
	Words	2.91 (0.40)	2.28 (0.41)	2.40 (0.42)	2.15 (0.43)
	Nonwords$_{LS}$	2.38 (0.36)	1.90 (0.46)	1.83 (0.45)	
	Nonwords$_{ON}$	1.49 (0.46)	1.39 (0.44)		1.84 (0.42)
LPC (600-700ms)					
	Words	3.46 (0.49)	3.71 (0.47)	3.84 (0.44)	4.03 (0.54)
	Nonwords$_{LS}$	3.62 (0.42)	3.24 (0.53)	3.67 (0.47)	
	Nonwords$_{ON}$	3.30 (0.54)	3.71 (0.52)		4.31 (0.50)
LPC (700-800ms)					
	Words	1.99 (0.43)	2.57 (0.48)	2.25 (0.42)	2.54 (0.51)
	Nonwords$_{LS}$	2.20 (0.38)	2.29 (0.47)	3.05 (0.42)	
	Nonwords$_{ON}$	2.66 (0.54)	2.82 (0.50)		3.31 (0.47)
LPC (800-1000ms)					
	Words	1.03 (0.32)	1.17 (0.37)	1.18 (0.40)	0.91 (0.42)

Nonwords$_{LS}$	0.98 (0.54)	1.13 (0.37)	1.78 (0.37)	
Nonwords$_{ON}$	1.35 (0.57)	1.68 (0.40)		1.66 (0.37)

Nonword$_{ON}$ trials. In the analysis of the early epoch of the posterior negativity for nonwords$_{ON}$, the main effect of block was not significant, $F(2,42)=1.00$, $p=0.38$, $\eta_p^2=0.05$. For the analysis of the late epoch of the posterior negativity for nonwords$_{ON}$, the main effect of block was not significant, $F(2,42)=1.11$, $p=0.34$, $\eta_p^2=0.05$. These results indicate that the neural processes associated with the posterior negativity were not engaged for nonword$_{ON}$ trials.

Late Positive Component

The grand-averaged ERP data portraying the LPC are presented in Figure 3.4. The LPC was present in 2 epochs (600-800ms and 800-1000ms) in Experiment 1, so the LPC was analyzed for these two epochs. Analysis of the LPC included 3 electrodes (P1, Pz and P2) and was performed separately for words, nonwords$_{LS}$ and nonwords$_{ON}$.

Word trials. In the analyses of the 600-800ms epoch of the LPC for word trials, the main effect of block was not significant, $F(3,63)=0.95$, $p=0.42$, $\eta_p^2=0.04$, indicating that the LPC did not differ in amplitude for control and PM blocks. This finding diverged from Experiment 1 and visual inspection of the waveforms indicates that the LPC may be present in a more narrow epoch between 700-800ms for words. Therefore, the LPC was analyzed in a 700-800ms epoch and the main effect of block was not significant, $F(3,63)=1.42$, $p=0.25$, $\eta_p^2=0.06$. Further analysis of the LPC for words at the 700-800ms epoch revealed no significant difference in the amplitude of the LPC for the Control words and the PM$_W$ words, $F(1,21)=3.57$, $p=0.07$, $\eta_p^2=0.15$. While this result was not significant, it is in the right direction. In the analyses of the 800-1000ms epoch of the LPC, the main effect of block was no significant, $F(3,63)=0.29$, $p=0.84$, $\eta_p^2=0.01$. These results reveal that the LPC was not present during word trials. This finding diverges from Experiment 1 in which the LPC was present for words from 600-800ms.

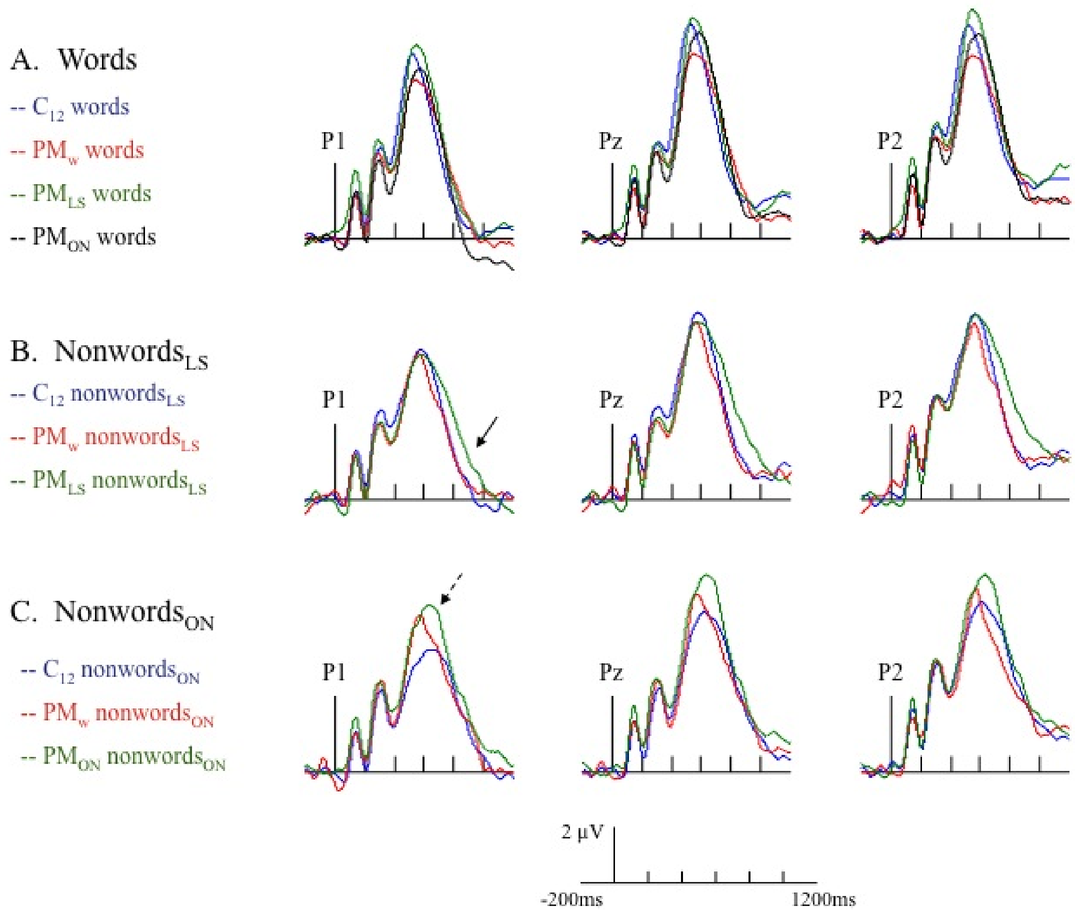

Figure 3.4. Grand-averaged ERPs portraying the LPC (*Note*: The solid arrow indicates the LPC from 800-1000ms. The dashed arrow indicates the LPC from 600-700ms).

Nonword_{LS} trials. In the analyses of the 600-800ms epoch of the LPC for nonword_{LS} trials, the main effect of block was not significant, $F(3,63)=1.21$, $p=0.31$, $\eta_p^2=0.05$, indicating that the LPC was not present during the 600-800ms epoch. The analysis of the LPC for the 800-1000ms epoch, the main effect of block was not significant, $F(2,42)=1.14$, $p=0.32$, $\eta_p^2=0.05$. These results reveal that the LPC was not engaged during nonword_{LS}

trials. These results diverge from Experiment 1 in which the LPC was present for nonword$_{LS}$ trials during the 800-1000ms epoch.

Nonword$_{ON}$ trials. In the analyses of the 600-800ms epoch of the LPC for nonword$_{ON}$ trials, the main effect of block was not significant, $F(3,63)=1.40$, $p=0.26$, $\eta_p^2=0.06$. Visual inspection of the waveforms indicates that the LPC is present in a 600-700ms epoch. The analysis of the LPC in the second (600-700ms) epoch revealed a significant main effect of block, $F(2,42)=4.84$, $p=0.01$, $\eta_p^2=0.19$. Further analysis revealed no significant difference in the amplitude of the LPC for the 600-700ms epoch for the PM$_W$ nonwords$_{ON}$ and the Control nonwords$_{ON}$, $F(1,21)=1.46$, $p=0.24$, $\eta_p^2=0.07$, so these trials were averaged together for further comparison. The LPC was greater in amplitude for the block PM$_{ON}$ nonwords$_{ON}$ than the average of the PM$_W$ nonwords$_{ON}$ and the Control nonwords$_{ON}$, $F(1,21)=8.52$, $p=0.01$, $\eta_p^2=0.29$. These results reveal that the LPC was greater in amplitude for the PM$_{ON}$ nonwords$_{ON}$ than the PM$_W$ and the Control nonwords$_{ON}$ during the 600-700ms epoch. The LPC was also analyzed in a 800-1000ms epoch and the main effect of block was not significant, $F(1,21)=0.33$, $p=0.72$, $\eta_p^2=0.01$. These results indicate that the LPC was present during a 600-700ms epoch for nonwords$_{ON}$ in the PM$_{ON}$ block.

Discussion

The present experiment was designed to test the idea that the posterior negativity is associated with an attentional filter that facilitates the processing of PM relevant information by differentiating stimuli based on existing lexical or semantic representations. If the differences in engagement of the neural processes associated with the posterior negativity found in Experiment 1 were due to the attentional filter using the lexical characteristics of words to separate stimuli, there would be differences in the amplitude of the posterior negativity for the letter string nonwords and orthographic neighbor nonwords. However, if the differences in engagement of the neural processes associated with the posterior negativity were due to the attentional filter using the semantic representations of words, the posterior negativity should distinguish word and orthographic neighbor stimuli.

The behavioral data indicated target checking for the PM_W and PM_{LS} blocks and retrieval mode for the PM_{LS} and PM_{ON} block. The findings of target checking but not retrieval mode for the PM_W block and target checking and retrieval mode for the PM_{LS} block are consistent with the results of Experiment 1.

Analysis of the physiological data revealed that the posterior negativity was present in two epochs (300-400ms and 400-500ms). In the 300-400ms epoch, the neural processes associated with the posterior negativity were engaged for word stimuli in the PM_W block and $nonword_{LS}$ stimuli in the PM_{LS} block. There was no evidence of the posterior negativity for the $nonword_{ON}$ stimuli in the PM_{ON} block. Examination of the 400-500ms epoch revealed that the posterior negativity was present for words in the PM_W block but not for $nonword_{LS}$ stimuli in the PM_{LS} block or $nonword_{ON}$ stimuli in the PM_{ON} block. These findings are consistent with the behavioral data, which indicated the presence of target checking for the PM_W and PM_{LS} blocks but not the PM_{ON} block, and provide further evidence that the posterior negativity is sensitive to target checking.

One new finding was that the posterior negativity was present for a longer amount of time in the current experiment. Participants engaged the neural processes associated with the posterior negativity during the entire epoch for the word stimuli in the PM_W block and recruited the neural processes associated with the posterior negativity in the early but not late portion of the posterior negativity for $nonword_{LS}$ stimuli in the PM_{LS} block. These findings support the differential recruitment of the neural processes associated with the posterior negativity found in Experiment 1; however, in Experiment 2 the differential recruitment was temporal rather than the amplitude difference found in Experiment 1. The posterior negativity was not present during either epoch for the nonword$_{ON}$ stimuli in the PM$_{ON}$ block. These results indicate that the presence of the posterior negativity is likely working as an attentional filter that participants may circumvent, as the posterior negativity was not present for the orthographic neighbor nonwords. The words have existing semantic and lexical representations that the attentional filter reflected in the posterior negativity is able to use to differentiate them from the PM irrelevant stimuli in a word PM block. When the letter string nonwords were cues, the posterior negativity was recruited so this attentional filter may be able to use a series of letters rather than a lexical representation to separate PM relevant information. The absence of the posterior negativity for orthographic neighbor nonwords is surprising as participants were able to complete the PM task. Perhaps the attentional filter was unable to differentiate the orthographic neighbor nonwords from the word stimuli because these nonwords are too structurally similar to the word stimuli.

Examination of the ERP waveforms revealed that the LPC may have been present at a 700-800ms epoch, but the analysis did not indicate the presence of the LPC for words, nonword$_{LS}$ or nonword$_{ON}$ stimuli. Additionally, the LPC may have been present in a 800-1000ms epoch, but the analysis did not indicate the presence of the LPC for any stimulus type. These results are not consistent with the findings of Experiment 1 in which the LPC was found to be sensitive to target checking. The LPC was present at a 600-700ms epoch for nonword$_{ON}$ stimuli. The nonword$_{ON}$ stimuli were more difficult as reflected in slower reaction times and decreased accuracy for these stimuli types, so this effect may be reflecting additional processing participants were engaging to complete the prospective task in the PM_{ON} block. Because orthographic neighbor nonwords have lexical representations but not semantic representations, the additional processing may involve searching for a semantic representation.

CHAPTER 4. EXPERIMENT 3

Introduction

Experiment 3 was designed to examine the nature of the difference in engagement of the neural processes associated with the LPC for words and nonwords found in Experiment 1. This differential engagement of the neural processes associated with the LPC may reflect differences in time course of memory retrieval for words and nonwords. In Experiment 1, the neural processes associated with the LPC were recruited earlier for words (600-800ms) than for nonwords (800-100ms). Perhaps the differential recruitment of these neural processes is due to the difficulty of maintaining the representation of the letter string nonwords used in Experiment 1. Word stimuli have existing representations in memory as individuals utilize words in daily language. In contrast, nonwords do not have existing representations, and an individual may require more time to retrieve the nonwords. If the LPC is reflective of retrieval process, this would explain why the neural processes associated with the LPC were engaged earlier for words than nonwords. This idea was tested by varying the number of prospective cues between blocks of trials in Experiment 3. Since reaction time increases as the number of items in a memory set increases (Sternberg, 1966), the LPC for the six cue condition should be present in a later epoch than the two cue condition if the LPC is reflective of retrieval processes.

Participants completed four blocks of trials. In the first and fourth block, participants completed the ongoing lexical decision task. In the second and third blocks of trials, participants completed the ongoing activity with the embedded prospective memory component of a key press when a stimulus was a prospective cue. The prospective cues in Experiment 3 were always words and the LPC was examined using two and six prospective cues. The number of prospective cues was varied such that participants completed one block with two (girls, decided) prospective cues and one block with six prospective cues (maybe, blue, below, member, husband, science). If the differences in temporal engagement of the neural processes associated with the LPC found in Experiment 1 were due to retrieval processes, retrieval would be faster in the two prospective cue condition than the six cue condition and the recruitment of the neural processes associated with the LPC for the two cue condition should be similar to the word trials in Experiment 1. Similarly, retrieval in the six prospective cue conditions should be slower than the two cue condition and the temporal engagement of the neural processes associated with the LPC should be similar to the nonword trials in Experiment 1.

Method

Participants

Twenty-eight Iowa State University students (14 male, 1 left-handed, 4 ambidextrous, *M*=20.0 years, range=18-35 years) participated in the experiment in exchange for course credit. Informed consent was obtained at the beginning of the study. Data for five participants were excluded from the analyses: one participant was excluded due to the failure to make any prospective responses, one participant was a non-native English speaker and three participants were excluded due to excessive movement artifact in the EEG data. Informed consent was obtained prior to participation in the study.

Materials

The materials used in Experiment 3 are similar to those used in Experiment 1.

Stimuli

The stimulus list consisted of 420 words and 420 nonwords. The words were chosen from the ELP database (Balota et al., 2007) and had an average frequency of *M*=138, *SD*=16.1 (Kucera & Francis, 1967) and an average wordlength of *M*=5.5, *SD*=0.7. The nonwords were created by moving the first syllable of a word target to the end of the word (Smith, 2003). The words and nonwords were divided into four stimulus lists to create three lists with 120 unique stimuli and one list with 60 unique stimuli. One stimulus list was presented in each block and the order of presentation for the first three stimulus lists were counterbalanced across conditions. Each target stimulus was presented twice in its given block resulting in a total of 840 trials.

The stimuli were presented in gray uppercase letters on a black background and displayed until participants made their response. The number of PM cues in a PM block varied between two items (girls, decided) and six items (maybe, blue, below, member, husband, science) such that one of the PM blocks contained two cues and one of the PM blocks had six cues. Sixteen words from each stimulus list were selected and removed from the list when the list was in a PM block. Either two or six of those items (depending on the prospective memory condition) was replaced by the PM cues while the other items served as controls for the PM items that match the PM targets for word length and frequency according to Kucera and Francis (1967) norms (control words: moral, neither, boys, trial, record, student, stopped, merely).

Design and Procedure

The task design was a 2 (prospective load: PM or NoPM) x 2 (retrieval set: 2 cues, 6 cues) factorial. The 840 trials were divided into three blocks of 240 trials and one block of

120 trials. The presentation of the three 240 stimulus lists was counterbalanced across participants for the first three blocks and the final block contained the same list for all participants (see Appendix E). The first block was always a NoPM block followed by two PM blocks followed by a NoPM block. The two PM blocks were counterbalanced across participants. Half of the subjects received the two PM cue block before the six PM cue block and this order was reversed for the other subjects.

The ongoing task for the experiment was a lexical decision task. Participants were presented with a letter string and asked to press the “n” key if the letter string was a word and the “m” key if the letter string was a nonword. Before the start of the PM blocks, individuals were shown the PM cues and given time to learn those words. They were then given two recognition and two recall tests to ensure that they had learned the PM cues (see Appendix F). Participants were told that they had the additional task of pressing the “v” key after making their lexical decision response when they encountered the PM cues in the experiment. The PM cues were presented on trials 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220 and 240. There was a surprise recognition test (see Appendix G) of the PM cues at the end of the experiment and every participant correctly identified the prospective cues.

EEG Recording Materials

The recording and processing of the EEG data were the same as Experiment 1. ERP epochs included data for correct responses where RT was less than 5,000 ms and excluded data from the initial trial in each block and the three trials before and after prospective cues. The ERP epoch included -200 to 1200 ms of activity around the onset of the stimulus. The electrodes chosen for measurements of the N300, prospective positivity and P3 were those used in studies reporting these ERPs. Electrodes chosen for measurements of the two ERPs (posterior negativity and late prospective complex) found in Experiment 1 were based on the electrodes used in Experiment 1.

Results

Behavioral Results

PM Cue Trials

The accuracy for prospective memory trials was similar when there were 2 prospective cues, *M*=0.95, *SD*=0.06, and 6 prospective cues, *M*=0.94, *SD*=0.09, $F(1,23)=1.00$, $p=0.33$, $\eta_p^2=0.04$. The reaction times were significantly slower for prospective cue trials in the 6 prospective cue condition, *M*=970, *SD*=50, than the 2 prospective cue condition, *M*=787, *SD*=20, $F(1,23)=18.27$, $p<0.001$, $\eta_p^2=0.44$. Reaction times for prospective cue trials in the 2 cue condition were significantly slower than ongoing word trials in the 2 cue condition, $F(1,23)=8.88$, $p=0.007$, $\eta_p^2=0.28$. Similarly, reaction times for prospective cue trials in the 6 cue condition were significantly slower than ongoing word trials in the 6 cue condition, $F(1,23)=22.18$, $p<0.001$, $\eta_p^2=0.49$. These results are similar to the findings of Experiments 1 and 2 and consistent with PM research findings of slower reaction times for PM trials than ongoing activity trials (Marsh et al., 2006).

Ongoing Activity Trials

Several trials were excluded from the analysis of ongoing trials: (a) the first two trials in each block; (b) PM cue trials; (c) the three trials proceeding and following PM trials; (d) trials where reaction times were greater than 5000ms; and (e) trials reflecting incorrect lexical decisions.

The response accuracy data are presented in Table 4.1. Analysis of the response accuracy data revealed that participants were significantly more accurate for Control_{12} words than $Control_{12}$ nonwords, $F(1,23)=27.05$, $p<0.001$, $\eta_p^2=0.54$. There were no significant differences in accuracy for PM_2 words and PM_2 nonwords, $F(1,23)=0.51$, $p=0.48$, $\eta_p^2=0.02$, or PM_6 words and PM_6 nonwords, $F(1,23)=0.09$, $p=0.77$, $\eta_p^2=0.00$.

Table 4.1 Accuracy for words and nonwords during ongoing trials

		PM_2	PM_6	Control
Words	M	0.97	0.97	0.98
	SD	0.03	0.04	0.02
$Nonwords_{LS}$	M	0.97	0.96	0.94
	SD	0.03	0.03	0.03

The reaction time data are presented in Table 4.2 and Figure 4.1. The reaction time data were analyzed for the presence of retrieval mode and target checking. The analysis of the reaction time for the PM_2 block revealed that reaction time for $Control_{12}$ nonwords was significantly slower than PM_2 nonwords, $F(1,23)=4.36$, $p=0.05$, $\eta_p^2=0.16$, which provides no evidence of retrieval mode for the PM_2 block. Reaction time for the PM_2 words was significantly slower than the $Control_{12}$ words, $F(1,23)=8.42$, $p=0.008$, $\eta_p^2=0.27$, providing evidence of target checking for the PM_2 block. Analysis of the reaction time for the PM_6 block revealed no significant difference in reaction time between $Control_{12}$ nonwords and PM_6 nonwords, $F(1,23)=2.69$, $p=0.12$, $\eta_p^2=0.11$, providing no evidence of retrieval mode. Reaction time for the PM_6 words was significantly slower than the $Control_{12}$ words, $F(1,23)=28.12$, $p<0.001$, $\eta_p^2=0.55$, providing evidence of target checking. These results indicate that participants utilized target checking but not retrieval mode for both the PM_2 and PM_6 blocks.

Table 4.2 Reaction time for words and nonwords during ongoing trials

		PM_2	PM_6	Control
Words	M	729	810	687
	SD	89	129	78
Nonwords	M	767	766	812
	SD	140	128	185

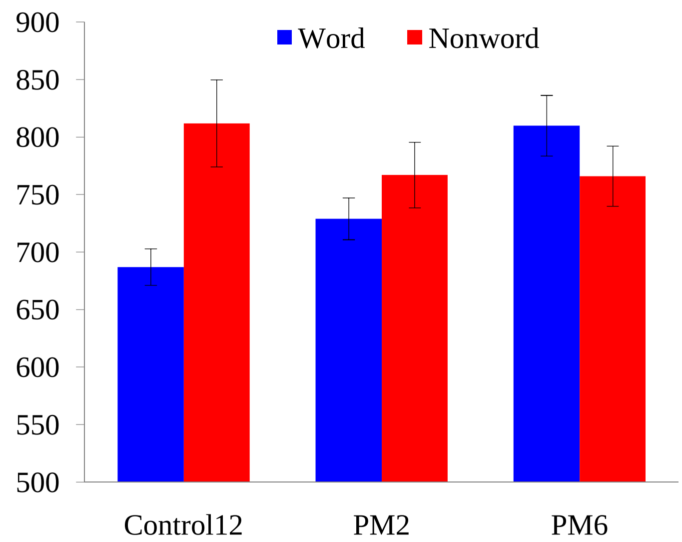

Figure 4.1 Reaction times for words and nonwords in Experiment 3.

ERP Results: Realizing an Intention

N300

The grand-averaged ERP data portraying the N300 are presented in Figure 4.2. These data reveal that the N300 does not appear to be present at the occipital-parietal electrodes.

The data were analyzed in a 4 (stimulus type: PM_2 word, PM_6 word, PM_2 cue, PM_6 cue) x 3 (electrode: PO9, Oz, PO10) ANOVA. The main effect of stimulus type was not significant, $F(3,66)=0.51$, $p=0.62$, $\eta_p^2=0.02$, indicating that the N300 was not engaged at the occipital-parietal electrodes in this experiment. Further inspection of the waveforms revealed that the N300 was present at electrode Iz so the data were analyzed in a 4 (stimulus type: PM_2 word, PM_6 word, PM_2 cue, PM_6 cue) design. The main effect of stimulus type was significant, $F(3,66)=3.54$, $p=0.04$, $\eta_p^2=0.14$. Post hoc analysis revealed no significant difference between PM_2 cues, PM_2 words and PM_6 words, $F(2,44)=2.14$, $p=0.16$, $\eta_p^2=0.09$, so these trials were averaged together for further analysis. There was a significant difference between PM_6 cues and the average of PM_2 cues, PM_2 words and PM_6 words, $F(3,66)=6.65$, $p=0.02$, $\eta_p^2=0.23$, indicating that the amplitude of the N300 was greater for PM_6 cues than other stimulus types. These results indicate that the neural processes associated with the N300 were engaged for the PM_6 cues and PM_2 cues but were only significantly greater in amplitude for the PM_6 cues.

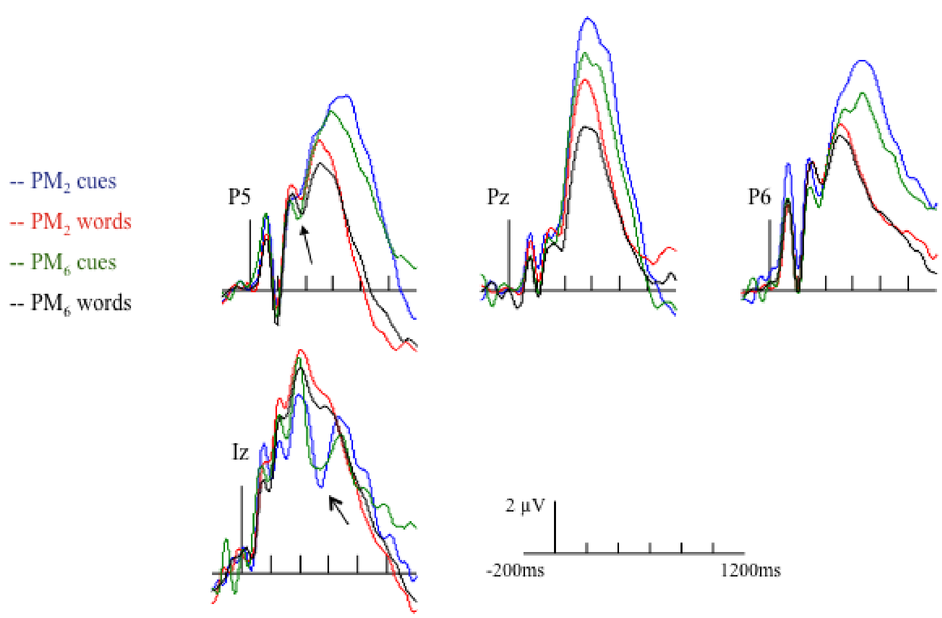

Figure 4.2 Grand-averaged ERP data portraying the N300.

Frontal Positivity

The grand-averaged ERP data portraying the frontal positivity are presented in Figure 4.3. The data were analyzed in a 4 (stimulus type: PM_2 word, PM_6 word, PM_2 cue, PM_6 cue) x 3 (electrode: FC1, FCz, FC2) design. The main effect of stimulus type was significant, $F(3,66)=7.12$, $p=0.002$, $\eta_p^2=0.24$. Post hoc analysis revealed no significant difference between PM cues in the PM_2 and PM_6 block, $F(1,22)=0.71$, $p=0.41$, $\eta_p^2=0.03$, so these trials were averaged together for further analysis. There was no significant difference between words in the PM_2 and PM_6 block, $F(1,22)=0.00$, $p=0.99$, $\eta_p^2=0.00$, so these trials were averaged together for further analysis. The frontal positivity was significantly larger in amplitude for the average of the PM cues than the average of the word trials, $F(1,22)=20.37$, $p<0.001$, $\eta_p^2=0.46$. These results indicate that the frontal positivity was present for the PM cues but was not present for the ongoing word trials.

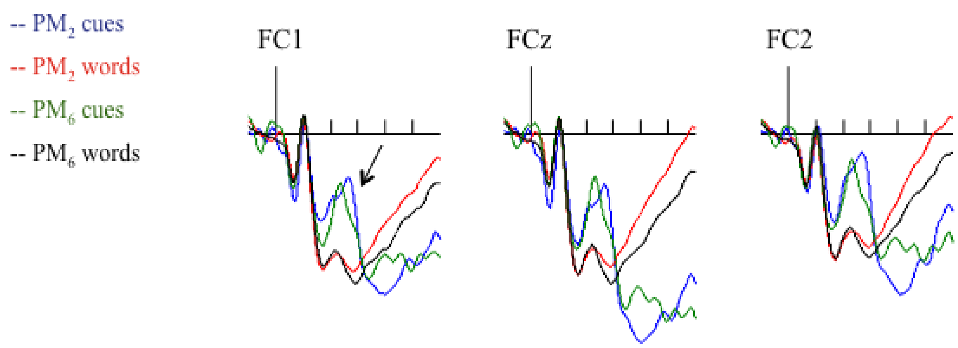

Figure 4.3 Grand-averaged ERP data portraying the frontal positivity.

Prospective Positivity

The grand-averaged ERP data portraying the prospective positivity are presented in Figure 4.3. These data reveal that the prospective positivity appears to be present in 2 epochs

(600-800ms and 800-1000ms) for both prospective memory conditions. The data were analyzed for each epoch in a 4 (stimulus type: PM_2 word, PM_6 word, PM_2 cue, PM_6 cue) x 3 (electrode: P3, Pz, P4) design. In the analysis of the 600-800ms epoch, the main effect of stimulus type was significant, $F(3,66)=19.01$, $p<0.001$, $\eta_p^2=0.46$. Post hoc analysis revealed no significant difference in amplitude of the prospective positivity for PM_2 words and PM_6 words, $F(3,66)=0.30$, $p=0.59$, $\eta_p^2=0.01$, so these trials were averaged together for further analysis. There was no significant difference in the amplitude of the prospective positivity for the PM_2 cues and PM_6 cues, $F(3,66)=3.15$, $p=0.09$, $\eta_p^2=0.13$. Additionally, the amplitude of the prospective positivity was greater for the PM_2 cue trials, $F(1,22)=34.50$, $p<0.001$, $\eta_p^2=0.61$, and the PM_6 cue trials, $F(1,22)=17.87$, $p<0.001$, $\eta_p^2=0.45$, than the ongoing word trials. These results indicate that the amplitude of the prospective positivity is greater for prospective memory cue trials than ongoing word trials during the 600-800ms epoch.

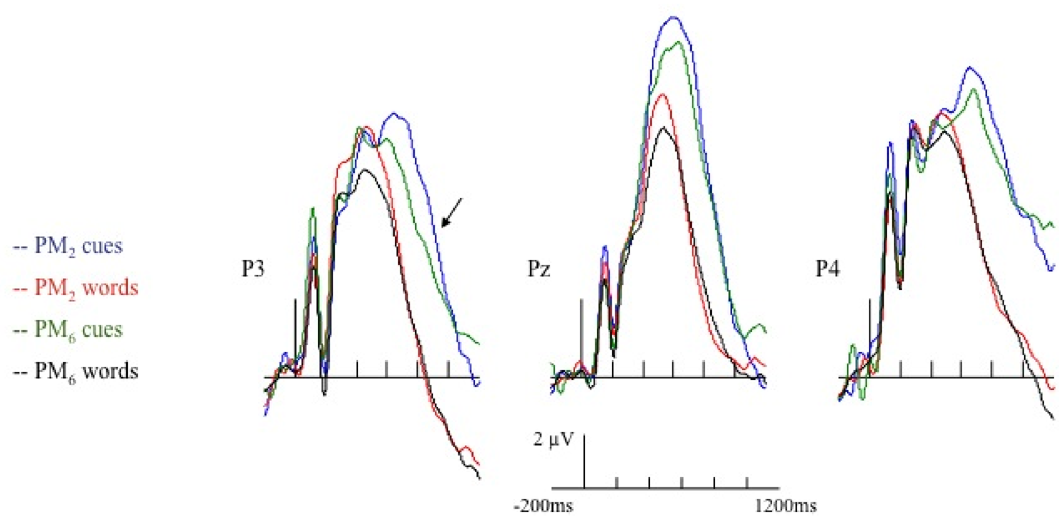

Figure 4.3 Grand-averaged ERPs portraying the prospective positivity.

In the analysis of the 800-1000ms epoch, the main effect of stimulus type was significant, $F(3,66)=7.47$, $p=0.002$, $\eta_p^2=0.25$. Post hoc analysis revealed no significant difference in the amplitude of the prospective positivity between PM_2 and PM_6 word trials, $F(1,22)=0.00$, $p=0.99$, $\eta_p^2=0.00$, so these trials were averaged together for further analysis. There were no significant differences in amplitude of the prospective positivity for the PM_2 cue trials and the PM_6 cue trials, $F(1,22)=2.48$, $p=0.13$, $\eta_p^2=0.10$. Additionally, the amplitude of the prospective positivity was greater for the PM_2 cue trials, $F(1,22)=14.22$, $p=0.001$, $\eta_p^2=0.39$, and the PM_6 cue trials, $F(1,22)=6.74$, $p=0.02$, $\eta_p^2=0.23$, than ongoing word trials. These results indicate that during the 800-1000ms epoch, the amplitude of the prospective positivity is greater for prospective cue trials than ongoing word trials.

Table 4.3. Mean voltages for the ERP data reflecting realizing an intention. The standard errors are in parentheses.

		PM cue	Ongoing Word
N300 at Iz			
	PM_2	1.47 (1.48)	3.44 (0.69)
	PM_6	0.63 (1.22)	2.98 (0.59)
Prospective Positivity 600-800ms			
	PM_w	6.77 (0.77)	3.34 (0.35)
	PM_{nw}	5.78 (0.78)	3.17 (0.44)
Prospective Positivity 800-1000ms			
	PM_w	3.70 (0.84)	0.95 (0.34)
	PM_{nw}	2.81 (0.83)	0.96 (0.38)

ERP Results: Target Checking

Posterior Negativity

The grand-averaged ERP data portraying the posterior negativity are presented in Figure 4.4 and the mean voltages for the ERPs reflecting target checking are presented in Table 4.4. Visual inspection of the ERP waveforms indicates that the posterior negativity was delayed relative to Experiments 1 and 2 as it was present from 400-500ms so the data were analyzed at this epoch. The posterior negativity was analyzed for words in a 3 (block: Control_{12} words, PM_2 words, PM_6 words) x 3 (electrode: P5, Pz, P6) design. For the analysis of words, the main effect of block was significant, $F(2,44)=3.61$, $p=0.04$, $\eta_p^2=0.14$. Post hoc analysis revealed no significant difference in the amplitude of the posterior negativity between Control_{12} words and PM_2 words, $F(1,22)=0.06$, $p=0.80$, $\eta_p^2=0.00$, so these trials were averaged together for further analysis. The amplitude of the posterior negativity was significantly larger for PM_6 words than the average of Control_{12} and PM_2 words, $F(1,22)=8.00$, $p=0.01$, $\eta_p^2=0.27$. The nonwords were analyzed in a 3 (electrode: P5, Pz, P6) x 3 (block: Control_{12} nonwords, PM_2 nonwords, PM_6 nonwords) design. In the analysis of the nonwords, the main effect of block was not significant, $F(2,44)=2.66$, $p=0.08$, $\eta_p^2=0.11$. These results indicate that the posterior negativity was engaged for word trials in the PM_6 block and that the posterior negativity was not engaged for nonwords in any block.

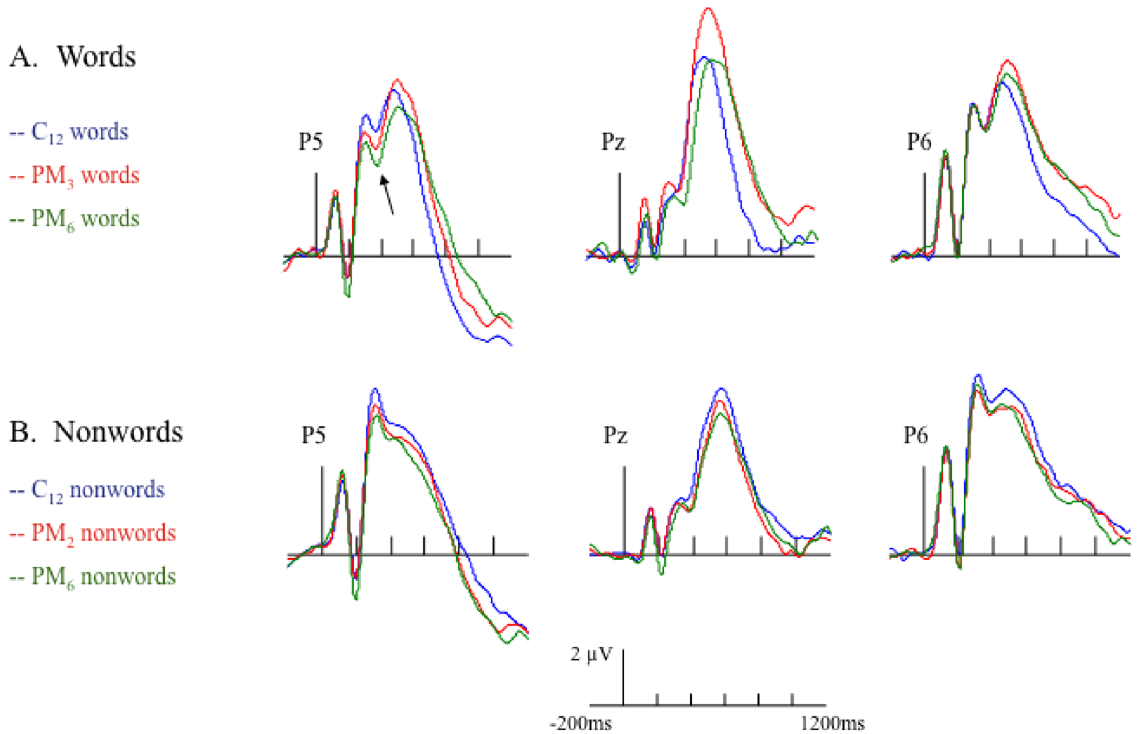

Figure 4.4 Grand-averaged ERPs portraying the posterior negativity.

Table 4.4. Mean voltages for the ERP data reflecting target checking. The standard errors are in parentheses.

		Words	Nonwords
Posterior Negativity 400-500ms			
	$Control_{12}$	2.91 (0.40)	2.28 (0.41)
	PM_2	2.38 (0.36)	1.90 (0.46)
	PM_6	1.49 (0.46)	1.39 (0.44)
LPC 600-800 ms			
	C_{12}	2.11 (0.34)	2.05 (0.34)
	PM_2	3.34 (0.35)	1.85 (0.41)
	PM_6	3.17 (0.44)	1.75 (0.35)
LPC 800-1000 ms			
	0.16 (0.35)	0.55 (0.28)	0.16 (0.35)
	0.95 (0.34)	0.34 (0.42)	0.95 (0.34)
	0.96 (0.38)	0.31 (0.31)	0.96 (0.38)

Late Positive Component

The grand-averaged waveforms representing the LPC are presented in Figure 4.5. Visual inspection of the ERP waveforms indicated that the LPC was present in two epochs (600-800ms and 800-1000ms) so the data were analyzed in both epochs. The analysis of words represented a 3 (block: Control_{12} words, PM_2 words, PM_6 words) x 3 (electrode: P3, Pz, P4) design. In the analysis of 600-800ms epoch for words, the main effect of block was significant, $F(2,44)=14.00$, $p<0.001$, $\eta_p^2=0.39$. Post hoc analysis revealed no significant difference in amplitude of the LPC between PM_2 words and PM_6 words, $F(1,22)=0.30$, $p=0.59$, $\eta_p^2=0.01$, so these trials were averaged together for further analysis. The amplitude of the LPC was significantly greater for the average of PM_2 and PM_6 words than the Control_{12} words, $F(1,22)=58.74$, $p<0.001$, $\eta_p^2=0.73$. These results indicate that the neural processes associated with the LPC were engaged for words in PM blocks but not words in the control block for the 600-800ms epoch.

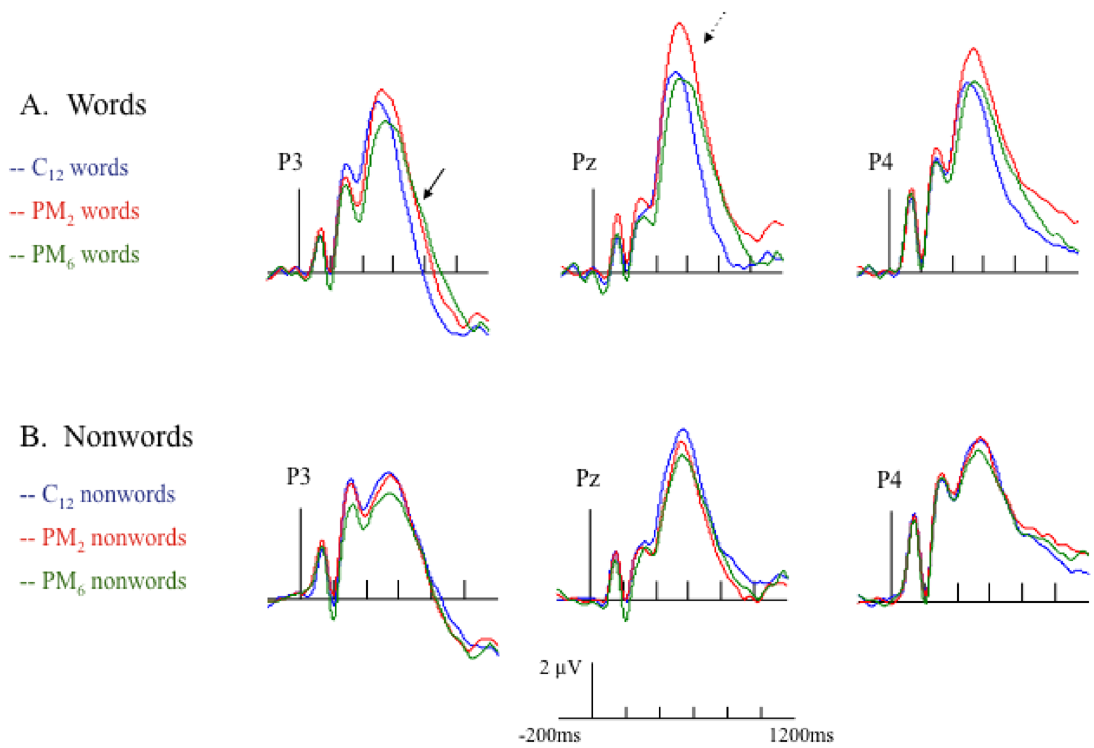

Figure 4.5 Grand-averaged ERPs portraying the late positive component. (*Note*: The solid arrow indicates the LPC while the dashed arrow indicates the P3).

In the analysis of the 800-1000ms epoch for words, the main effect of block was significant, $F(2,44)=4.26$, $p=0.02$, $\eta_p^2=0.16$. Post hoc analysis revealed no significant amplitude differences between PM_2 words and PM_6 words, $F(1,22)=0.00$, $p=0.99$, $\eta_p^2=0.00$, so these trials were averaged together for further analysis. The amplitude of the LPC was significantly greater for the average of PM_2 and PM_6 words than $Control_{12}$ words, $F(1,22)=14.58$, $p=0.001$, $\eta_p^2=0.40$. These results indicate that during the 800-1000ms epoch the LPC was engaged for word trials in PM blocks but not for word trials in the control blocks.

The analysis of the LPC for words revealed two unexpected results: no difference in recruitment of the neural processes associated with the LPC for the PM_2 and PM_6 cue word trials and the presence of the P3 component. The hypothesis of Experiment 3 was that there would be differences in the presence of the LPC for word trials in the PM_2 cue and PM_6 cue condition. Further examination of the waveforms indicated that the P3 was present for the PM_2 word trials, which may have affected the ability to analyze the LPC. The LPC was present over the left hemisphere. Therefore, the P3 was analyzed for words to verify its presence in the PM_2 block and the LPC was analyzed over the left hemisphere.

Visual inspection of the ERP waveforms revealed that the P3 was present from 450-550ms. The analysis of the P3 reflected a 3 (electrode: P3, Pz, P4) by 3 (block: $Control_{12}$, PM_2, PM_6) design. The main effect of block was significant, $F(2,44)=5.16$, $p=0.01$, $\eta_p^2=0.19$. Post hoc analysis revealed no significant difference between $Control_{12}$ words and PM_6 words, $F(1,22)=1.78$, $p=0.20$, $\eta_p^2=0.08$, so these trials were averaged together for further analysis. Further analysis revealed that the amplitude of the P3 was greater for the PM_2 words than the average of $Control_{12}$ words and PM_6 words, $F(1,22)=7.33$, $p=0.01$, $\eta_p^2=0.25$. These results indicate that the P3 was engaged for the PM_2 block, but not the PM_6 or $Control_{12}$ blocks. This finding could explain why there was no significant difference in amplitude of the LPC between the PM_2 word trials and the PM_6 word trials at the electrodes used in Experiment 1. The LPC appeared to be present over the left hemisphere so further analyses examined the LPC over the left hemisphere.

The grand-averaged ERPs portraying the LPC over the left hemisphere are presented in Figure 4.6. The analysis of the LPC over the left hemisphere involved a 3 (block: $Control_{12}$, PM_2, PM_6) x 3 (electrode: P3, P5, P7) design for the 600-800ms epoch and the 800-1000ms epoch. In the analysis of the 600-800ms epoch of the LPC, the main effect of block was significant, $F(2,44)=6.63$, $p=0.003$, $\eta_p^2=0.23$. Post hoc analysis revealed no significant difference between PM_2 words and PM_6 words, $F(1,22)=0.67$, $p=0.42$, $\eta_p^2=0.03$, so these trials were averaged together for further analysis. There was a significant difference in amplitude of the LPC on the left hemisphere between the average of PM_2 and PM_6 and $Control_{12}$ words, $F(1,22)=10.29$, $p=0.004$, $\eta_p^2=0.32$, indicating that the amplitude of the LPC was greater for PM_2 and PM_6 words. These results indicate that the amplitude of the LPC for the 600-800ms epoch on the left hemisphere was greater for word trials in PM blocks than word trials in control blocks.

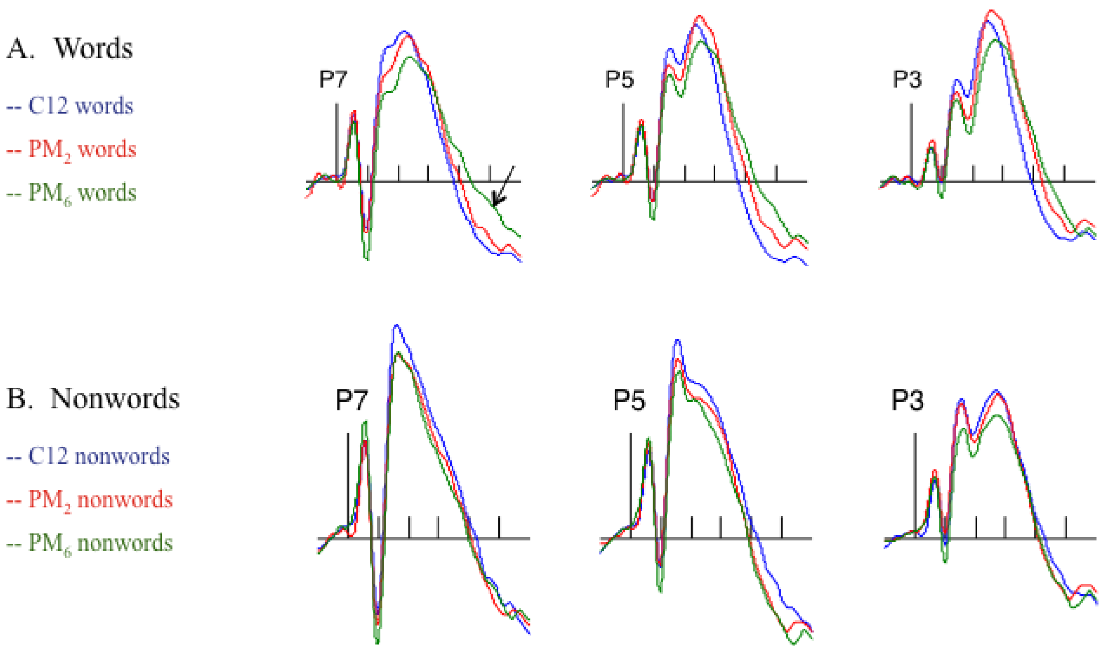

Figure 4.6 Grand-averaged ERPs portraying the late positive component over the left hemisphere.

In the analysis of the 800-1000ms epoch of the LPC, the main effect of block was significant, $F(2,44)=6.93$, $p=0.004$, $\eta_p^2=0.24$. Post hoc analysis revealed that the amplitude of the LPC was greater for PM_2 words trials, $F(1,22)=4.26$, $p=0.05$, $\eta_p^2=0.16$, and PM_6 word trials, $F(1,22)=9.72$, $p=0.005$, $\eta_p^2=0.31$, than $Control_{12}$ word trials. Additionally, the amplitude of the LPC between 800-1000ms on the left was greater for PM_6 word trials than PM_2 word trials, $F(1,22)=4.54$, $p=0.04$, $\eta_p^{2}=0.17$. These results indicate that the amplitude of the LPC in the 800-1000ms epoch over the left hemisphere was greater for word trials in the six prospective cue condition than the two prospective cue condition and greater for PM blocks than control blocks.

The analysis of nonwords represented a 3 (block: $Control_{12}$ nonwords, PM_2 nonwords, PM_6 nonwords) x 3 (electrode: P3, Pz, P4) design. In the analysis of the 600-800ms epoch, the main effect of block was not significant, $F(2,44)=0.59$, $p=0.56$, $\eta_p^{2}=0.03$. Similarly, in the analysis of the 800-1000ms epoch, the main effect of block was not significant, $F(2,44)=0.32$, $p=0.72$, $\eta_p^{2}=0.01$. These results indicate that the neural processes associated with the LPC were not engaged for nonwords in this experiment.

Discussion

Experiment 3 was designed to examine whether the difference in the amplitude of the LPC for words and nonwords in Experiment 1 might be related to differences in retrieval demands. In Experiment 1, the LPC was present for words in an early 600-800ms epoch and present for nonwords during a late 800-1000ms epoch. Nonwords were presumably more difficult to retrieve from memory as they lack an existing representation that words have. Since reaction time for a task increases as the number of items in a memory set increases (Sternberg, 1966), this idea could be tested by varying the number of PM cues. If the differential engagement of the neural processes associated with the LPC was due to retrieval processes, the LPC should distinguish the two PM cue condition from the six PM cue condition.

The behavioral data provided evidence of target checking but not retrieval mode for both PM blocks, which is consistent with the behavioral results of Experiments 1 and 2. Examination of the physiological data revealed the presence of three modulations of the ERPs that have previously been associated with the realization of a delayed intention: the N300, frontal positivity and prospective positivity. Analysis of the N300 revealed that it was present for PM cues in both PM blocks but only significant for PM cues in the PM_2 block. Examination of the ERP waveforms indicates that the N300 is present for PM cues in both blocks so the lack of significance in the PM_2 cue block is likely due to the limited number of PM cues used in this experiment. The frontal positivity is reported in studies of PM as a positive frontal reflection of the N300. The analysis of the frontal positivity in this experiment revealed that the frontal positivity was present for the PM cues but not the ongoing word trials. This finding is consistent with previous studies of PM that report the frontal positivity for PM cues (West et al., 2001; West and Krompinger, 2005). A final ERP modulation associated with the realization of delayed intentions present in this study is the prospective positivity. Analysis of the prospective positivity revealed that the prospective positivity was present for PM cues in the PM_2 and PM_6 block for both a 600-800ms and 800-1000ms epoch. This finding was consistent with the findings of Experiment 1.

Analysis of the physiological data associated with target checking revealed the presence of the posterior negativity and the LPC. The posterior negativity was greater in amplitude for words in the PM_6 block than the PM_2 and $Control_{12}$ blocks. This result diverges from the findings of Experiment 1 in which the posterior negativity was present for words in the PM word block. The LPC was examined over the left hemisphere due to the recruitment of the neural processes associated with the P3. The analysis of the LPC indicated that the

LPC was present for words in the PM blocks during the 600-800ms epoch and greater in amplitude for the words in the PM_6 block than the PM_2 block during the 800-1000ms epoch. The LPC shares features with the parietal old-new effect, which is typically observed between 300-800ms after stimulus onset and is greater in amplitude over the left hemisphere for old items relative to new items indicating that it is related to retrieval processes. These results indicate that the LPC may be due to retrieval processes as it was greater in amplitude for words in the PM_6 block than the PM_2 block.

CHAPTER 5. GENERAL DISCUSSION

The primary goal of this investigation was to examine the neural correlates of target checking in prospective memory. The Multiprocess and PAM theories of PM hold that strategic monitoring is important for the successful retrieval of delayed intentions, and the RM + TC theory of strategic monitoring posits that strategic monitoring is comprised of two processes: retrieval mode and target checking. Retrieval mode is a sustained process described as a cognitive state of readiness to encounter a prospective cue. Target checking is a transient process of checking the environment for potential cues when in an appropriate context. Numerous studies of PM have provided evidence of retrieval mode (West, Scolaro & Bailey, 2011; Guynn, 2003; Smith, 2003) yet no compelling evidence of target checking has been demonstrated in the extant ERP literature. In this dissertation, three experiments were performed to examine the neural and behavioral correlates of target checking.

Experiment 1 was designed to identify the ERP components sensitive to target checking using a lexical decision task that is commonly utilized in studies of PM (Marsh et al., 2003; Smith, 2003). Two ERP components were sensitive to target checking: the posterior negativity and the late positive component. The posterior negativity represents a negative deflection of the ERPs over the parietal region between 300-400ms. When words were PM cues, the posterior negativity distinguished words from nonword. In contrast, when PM cues were nonwords the posterior negativity did not distinguish words from nonwords. The LPC distinguished words from nonwords earlier (600-800ms) when the PM cue was a word and later (800-1000ms) when the PM cue was a nonword. The results of Experiment 1 indicate that the neural processes associated with target checking are differentially sensitive to the nature of the PM cues.

In Experiment 2, I hypothesized that the differential recruitment of the neural processes associated with the posterior negativity observed in Experiment 1 is related to the stability of the representation of the stimuli that served as PM cues. Words have lexical characteristics and semantic representations that the nonwords from Experiment 1 lack, and these differences between words and nonwords could influence target checking early in the stream of stimulus processing. Target checking could operate like an attentional filter that would facilitate information relevant to the retrieval of the delayed intention. Therefore, a PM cue with a stable representation would be beneficial for the retrieval of delayed intentions as the attentional filter could use this representation to separate PM relevant from PM irrelevant information. Perhaps the posterior negativity is associated with an attentional filter and the differences in the recruitment of the neural processes associated with the posterior negativity in Experiment 1 are due to the words having stable lexical and semantic representations. To test this idea in Experiment 2, the wordiness of the nonword stimuli was varied by using two types of nonwords: orthographic neighbor nonwords and letter string nonwords. Orthographic neighbor nonwords share lexical characterstics but not semantic representations with words, so differences in the presence of the posterior negativity between words and orthographic neighbor nonwords could be attributed to the attentional filter using semantic representations. Any differences in the engagement of the neural processes associated with the posterior negativity between letter string nonwords and orthographic neighbor nonwords could be attributed to the attentional filter utilizing lexical characteristics of the orthographic neighbor nonwords. The results of Experiment 2 revealed that the posterior negativity may reflect an attentional filter and that particpants may be able to circumvent this filter as the posterior negativity was not present for orthographic neighbor nonwords.

The goal of Experiment 3 was to examine the differential recruitment of the neural processes associated with the LPC for word and nonwords. I hypothesized that the LPC is associated with memory retrieval processes. Since individuals utilize words in daily language, word stimuli have existing representations in memory. In contrast, nonwords likely do not have existing representations making them more difficult to retrieve, which could produce the effect of cue type on the LPC in Experiment 1. To test this prediction, the number of PM cues was varied between blocks of trials in Experiment 2. If the LPC is associated with memory retrieval processes, the LPC should be greater in amplitude for the six cue condition relative to the two cue condition. The results of Experiment 3 indicated that the LPC was present for words between 600-800ms and greater in amplitude for words in the PM_6 block than the PM_2 block. The findings of Experiment 3 support the hypothesis that the LPC is related to retrieval processes that may support target checking.

The findings of the present investigation have important implications for the field of prospective memory. In this chapter, the extension of the existing literature is discussed. First, the implications of the behavioral results are examined. The behavioral data illustrate that retrieval mode and target checking can be differentiated at the behavioral level of analysis. Second, the extension of the existing ERP literature is described. The prospective positivity was present for word and nonword cues, which is a novel finding. Third, the new physiological findings of the posterior negativity and LPC are discussed. Finally, the implications for the existing theories of PM are examined.

I. Behavioral Data

A major extension of the PM behavioral literature from the present investigation is the demonstration of evidence for both retrieval mode and target checking in the reaction time data which extends the RM + TC theory. As a sustained cognitive state of readiness, retrieval mode would be difficult to turn on and off during PM tasks. Therefore, evidence of retrieval mode was defined as slower reaction times for the irrelevant stimuli in a PM block (e.g., slower reaction times for words when PM cues are nonwords). In contrast, target checking is a transient process of checking the environment for potential PM cues that may be more flexibly implemented over trials. Evidence of target checking was defined as slower reaction times for the relevant stimuli in a PM block (e.g., slower reaction times for nonwords when PM cues are nonwords). The behavioral results provided evidence of both retrieval mode and target checking in the three experiments. Importantly, the presence of retrieval mode and target checking depended on the type of PM cue.

Table 5.1 Summary of the evidence for retrieval mode and target checking in Experiments 1, 2 and 3. (*Note*: “+” denotes behavioral evidence for retrieval mode or target checking, “-“ indicates no behavioral evidence for retrieval mode or target checking and “~” indicates no significant evidence but that the effect was in the correct the direction).

	PM Cue Type	Retrieval Mode	Target Checking
Experiment 1			
	Word	-	+
	Nonword_{LS}	+	+
Experiment 2			
	Word	-	+
	Nonword_{LS}	+	+
	Nonword_{ON}	+	~
Experiment 3			
	Word	-	+

Table 5.1 summarizes the behavioral evidence for target checking and retrieval mode. Experiments 1 and 2 provide evidence of retrieval mode for the nonword stimuli. This finding is novel and it indicates that retrieval mode can be present without target checking. Experiments 1, 2 and 3 provide evidence of target checking for all cue types although the evidence for target checking for the orthographic neighbor nonwords is weak. These findings extend the ideas of PAM by providing evidence for two processes underlying strategic monitoring (target checking and retrieval mode).

The behavioral results of the three experiments revealed that target checking was engaged when PM cues were words and nonword stimuli. In contrast, retrieval mode was engaged when PM cues were nonword_{LS} and nonword_{ON} stimuli and not when PM cues were words. These findings indicate that participants may be able to engage in target checking without retrieval mode when the PM cue is a familiar stimulus (i.e., a word in these three experiments). Words are common stimuli that individuals view on a daily basis, so the completion of a PM task in which the cue is a word may not require the engagement of a sustained process in the current study. However, nonwords are unfamiliar stimuli so sustained processing associated with retrieval mode may be necessary to complete a PM task in which the cue is less familiar. An analogous real world example might be purchasing a gallon of milk on the ride home from work versus purchasing a gallon of milk while on vacation. The grocery store near home is a familiar PM cue. An individual would know what the store looks like and might not need to spend cognitive resources to prepare to encounter the cue. A grocery store encountered while on vacation would likely be an unfamiliar PM cue and an individual would need to spend cognitive resources (i.e., engage retrieval mode) to prepare to encounter the cue as the appearance and location of the store would be unknown.

An additional finding of the present study is the extension of the findings of Smith (2003). In traditional investigations of PM, the irrelevant stimuli in the lexical decision task are not included in the analysis of the behavioral results. Using a paragidgm developed by Cohen et al. (2009), the findings of the current study illustrate that there is important conceptual information represented in cue irrelevant trials that is missed in traditional investigations of PM. Future investigations of PM should examine both relevant and irrelevant stimuli types to provide a better understanding of the cognitive processes associated with PM.

II. ERPs and Realizing Intentions

I examined three modulations of the ERPs related to realizing a delayed intention. One neural correlate of PM is the N300, which is associated with detection of a prospective cue. Previous investigations of PM have demonstrated that the N300 is elicited when cues are defined by various characteristics of the stimuli such as letter case (West et al., 2001), color (West & Ross-Munroe, 2002) and word identity (West et al., 2000). To date the N300 has only been examined for PM cues that have preexisting representations in memory.

The N300 was examined in Experiments 1 and 3. In Experiment 1, the N300 was present when PM cues were words but not when PM cues were nonwords. This finding supports previous evidence, which reports the N300 for stimuli with preexisting representations that nonwords lack. The findings of Experiment 3 also converged with the preexisting literature as the N300 was present for word cues. However, the N300 was only significant for the PM_6 cue block, which is likely due to the low signal to noise ratio present for cues used in Experiment 3.

A second neural correlate of PM examined in this dissertation is the frontal positivity. This modulation of the ERPs is typically reported as a positive frontal reflection of the N300. In Experiment 1, the frontal positivity was greater in amplitude for words than nonwords when PM cues were words. When PM cues were nonwords, the frontal positivity was similar in amplitude for words and nonwords but different in amplitude for ongoing trial stimuli in PM blocks than no PM blocks. In Experiment 3, the frontal positivity was present for both PM_2 cue and PM_6 cue trials. These results indicate that frontal/posterior interactions may support target checking as the neural processes associated with the frontal positivity and posterior negativity were recruited similarly in Experiment 1 and 3.

The prospective positivity is associated with retrieving an intention from memory and the configuration of the prospective response. In Experiment 1, the prospective positivity was present for word and nonword cues and was greater in amplitude for nonword PM cues. This result indicates that the N300 but not the prospective positivity may be limited to stimuli with preexisting representations. This finding indicates that memory retrieval processes associated with the prospective positivity can operate without cue detection, which is consistent with the Multiprocess Theory's idea that an effective PM system should be flexible and able to use both strategic monitoring and spontaneous retrieval. In Experiment 3, the prospective positivity was elucidated for both PM_2 cues and PM_6 cues and there were no significant amplitude differences between the two cue types. If the prospective positivity was associated with memory retrieval processes, it should be greater in amplitude for the six cue condition than the two cue condition. Therefore, the results of Experiment 3 indicate that the prospective positivity may reflect the configuration of retrieval rather than memory retrieval processes. The results of this dissertation converge with previous studies that have found that the prospective positivity distinguishes PM cue trials from ongoing activity trials (West et al., 2001; West et al., 2003; West & Wymbs, 2004; West et al., 2006).

III. ERPs and Target Checking

The current investigation revealed several ERP components that reflected differential neural activity for ongoing trials in the PM conditions relative to the control blocks. The posterior negativity reflected a negativity over the occipital-parietal region between 300-500ms. When the PM cue was a word, the posterior negativity was greater in amplitude for word trials than other trials in Experiments 1, 2 and 3. When the PM cue was a nonword, the posterior negativity was greater in amplitude for nonwords than words but was greater in amplitude for words than trials in a control block in Experiment 1. In Experiment 2, there were differences in the time course of the posterior negativity for words and letter string nonwords. For the orthographic neighbor nonwords, the posterior negativity was not present.

The posterior negativity appears to be sensitive to variations in the representation of stimuli as the neural processes associated with the posterior negativity were differentially recruited for words, letter string nonwords and orthographic neighbor nonwords. Words possess stable lexical representations that letter string nonwords lack and semantic representations that letter string and orthographic neighbor nonwords lack. A stable representation would be beneficial for the retrieval of delayed intentions if target checking involves an attentional filter, which would facilitate relevant stimuli in the environment to allow for processing of PM cues. In Experiment 2, the “wordiness” of the nonword stimuli was varied using orthographic neighbor nonwords and letter string nonwords to examine the idea of the posterior negativity reflecting an attentional filter. Any differences in recruitment of the neural processes associated with the posterior negativity between letter string and orthographic neighbor nonwords were attributed to the attentional filter using lexical characteristics. In contrast, any differences in recruitment of the neural processes associated with the posterior negativity between words and orthographic neighbor nonwords were attributed to the attentional filter using semantic representations. The results of Experiment 2 revealed that the posterior negativity was not recruited for orthographic neighbor nonwords, but was present for letter string nonwords and words. This finding indicates that the posterior negativity is sensitive to variations in the representations of stimuli and that the attentional filter associated with the posterior negativity can be circumvented by participants. When orthographic neighbor nonwords were PM cues, the posterior negativity was not present yet participants were able to complete the PM task. Perhaps the attentional filter was able to differentiate the orthographic neighbor nonwords from the word stimuli because they share lexical characteristics.

These results indicate that the characteristics of a PM cue are important as an attentional filter is sensitive to cues with stable representations. Words are a familiar stimuli that individuals experience on a daily basis while nonwords are not familiar stimuli. When an individual uses an unfamiliar PM cue, the PM task requires more cognitive and neural resources for the attentional filter, which would result in larger costs to the ongoing activity. For example, purchasing a gallon of milk on vacation at an unfamiliar grocery store would result in greater costs to the ongoing activity than the PM task of purchasing a gallon of milk on the way home from work at a local grocery store. In the former situation, an individual needs to allocate more neural resources to monitoring for the PM cue of an unfamiliar grocery store, which would result to greater costs of the ongoing activity (i.e., driving). This indicates that characteristics of PM cues are important and unfamiliar cues can result in greater costs to ongoing activities.

The LPC was also associated with target checking and reflected a positivity over the parietal region between 600-1000ms. When PM cues were words, the LPC was greater in amplitude for word trials than other stimulus types between 600-800ms but the LPC was not present between 800-1000ms in Experiment 1. When PM cues were letter string nonwords, the LPC was greater in amplitude for nonword trials than other stimulus types between 800-1000ms in Experiment 1. In Experiment 2, the LPC did not differ for words or letter string nonwords. The LPC was present between 600-700ms over the parietal region for orthographic neighbor nonwords when PM cues were orthographic neighbor nonwords. This slow effect was not present for other stimulus types in Experiment 2. Participants were less accurate and had slower reaction times for the orthographic neighbor nonword trials so it is possible that this slow effect is due to the difficulty in the type of processing required for the orthographic neighbor nonwords. In Experiment 3, the LPC was present for words in PM blocks between 600-800ms and 800-1000ms and was greater in amplitude for words in the PM_6 block than the PM_2 block.

The LPC may be associated with memory retrieval processes. In Experiment 1, the LPC was greater in amplitude for words during an earlier than nonwords. Words have stable representations as they are used in daily language, but nonwords do not. Therefore, retrieving nonwords from memory would presumably be more difficult and time consuming. This idea was tested in Experiment 3 by varying the number of PM cues across blocks. If the LPC reflected memory retrieval processes, I hypothesized that the LPC would differentiate a six PM cue condition from a two PM cue condition. As the number of items in a memory set increases, the amount of cognitive resources required to complete a task increase (Sternberg, 1966). Thus, the LPC was hypothesized to be greater in amplitude for the six cue condition if the LPC was reflective of memory retrieval processes. The results of Experiment 3 provided evidence for this hypothesis, as the LPC was greater in amplitude for words in the PM_6 block than the PM_2 block.

The results for the LPC illustrate that the number of PM cues an individual needs to retrieve from memory is important. The number of PM cues was related to the amount of neural processes required to complete a task. When participants needed to maintain six cues in memory, the LPC was greater in amplitude relative to when there were two cues. The allocation of additional neural resources for the completion of a PM task with six cues illustrates that it is more difficult than a task with only two cues. In the real world, this means that the more PM cues an individual is maintaining in memory, the more difficult the PM task. For example, purchasing six items from the grocery store is a more difficult PM task than purchasing two items and it requires more neural resources. These more difficult PM tasks divert resources from ongoing activities and result in costs to ongoing activities.

IV. Implications for Existing Theories of Prospective Memory

The current investigation has important implications for current theories of PM. Prior to this study, researchers focused only on the relevant ongoing stimuli during a PM task to provide evidence of strategic monitoring. If the ongoing task was a lexical decision task with the PM component of a key press in response to a PM cue (word), the researchers would disregard the irrelevant stimuli (nonwords) during analysis of the behavioral data. The current data provide evidence that this common practice can obscure important data that is present in the irrelevant nonword stimuli. Future investigations of PM need to focus on both the relevant and irrelevant stimuli in an ongoing task.

This study also provides evidence that strategic monitoring is important for PM, which supports the views of both theories of PM. When the PM component was added to the lexical decision task, reaction time increased indicating that additional attentional resources were required to complete the task. Both the PAM and Multiprocess Theory hold that strategic monitoring requires attentional resources and is important for PM.

The RM + TC model of strategic monitoring (Guynn, 2003) proposed that strategic monitoring is supported by two types of processes: retrieval mode and target checking. Prior to the current investigation, there was little compelling evidence of retrieval mode and no evidence of target checking in the ERP literature. This dissertation provides evidence that target checking is supported by at least two types of processes: the posterior negativity and the LPC. The posterior negativity appears to be associated with an attentional filter that is flexible for the characteristics of stimuli while the LPC may be related to memory retrieval processes. One additional component of the ERPs was present for orthographic neighbor nonwords are may be engaged when participants are not able to use the attentional filter associated with the posterior negativity. This would explain the behavioral evidence of target checking when PM cues were orthographic neighbor nonwords.

These ERPs advance Guynn’s (2003) RM + TC model of strategic monitoring by providing evidence of two ERPs sensitive to target checking. The results of this study indicate that target checking involves a neural process (posterior negativity) that appears to separate stimuli based on the characteristics of the stimulus and a neural process (LPC) that is related to memory retrieval processes. Additionally, the behavioral data provides evidence that there can be retrieval mode without target checking as well as target checking without retrieval mode. This finding reveals that the cognitive processes used by participants during strategic monitoring are flexible and participants may utilize one or both processes based on the demands of the task.

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APPENDIX A. STIMULI USED IN EXPERIMENT 1

LIST 1			LIST 2		
words	freq	nonwords	words	freq	nonwords
points	143	tionna	army	132	aidp
lead	129	dingrea	cause	130	aless
hour	144	ausec	former	131	deasi
average	130	howeds	letter	145	iecep
size	138	terlet	list	133	lyclear
friend	133	dyrea	nation	139	lynear
step	131	myar	reading	140	ningeve
chance	131	istl	ready	143	onthm
deal	142	merfor	showed	141	quares
anyone	140	mersum	summer	134	rectdi
fine	161	selfmy	blood	121	alkedw
cent	158	asesc	bring	158	arec
main	119	domfree	carried	125	assedp
forms	128	wardfor	cases	148	diora
running	123	loorf	county	155	dredhun
final	156	ilarsim	design	114	edlearn
latter	114	armf	farm	125	eedf
based	119	pressex	figures	113	eedsn
hotel	126	riendsf	floor	158	eignfor
simply	170	jectsub	forward	115	erlow
shown	166	gerlar	freedom	128	estr
couple	122	lylike	friends	162	fortsef
stock	147	dlemid	green	116	greede
length	116	torys	image	119	hargec
cold	171	ovem	island	167	hiefc
earth	150	tycoun	labor	149	icalmed
central	164	lacedp	larger	123	ingmov
doing	163	lantp	likely	151	ivedl
plans	113	reeng	meaning	127	nercor
picture	162	erriv	meeting	159	neso
account	117	lanep	middle	118	ngera
window	119	ringb	move	171	oodf
fine	161	ingmean	myself	129	ornb
numbers	125	allw	nuclear	115	oubtd
types	116	riedcar	parts	113	pearap
indeed	162	loodb	placed	126	plesim
answer	152	ageim	plane	114	posepur
horse	117	signed	plant	125	prings
quality	114	artsp	police	155	riedt
club	145	uresfig	river	165	roupsg
fear	127	ermst	serious	116	rowthg
include	113	clearnu	similar	157	sicba
served	120	estt	single	172	spectre
added	172	orts	sort	164	tands
earlier	146	glesin	stop	120	tepss
results	149	licepo	story	153	ternpat
hear	153	borla	subject	161	tinget
hall	152	landis	terms	163	tireen
market	155	ingmeet	test	119	artst
slowly	115	riousse	wall	160	uralnat

LIST 3			LIST 4		
words	freq	nonwords	words	freq	nonwords
sales	133	ointsp	method	142	tentex
clearly	128	yonean	higher	160	ostl
paid	145	ourh	opened	131	portre
month	130	riendf	easy	125	taffs
square	143	izes	sent	145	aithf
evening	133	erageav	fall	147	steadin
nearly	141	hancec	paper	157	ingcom
ideas	143	eadl	trying	163	ingsay
piece	129	teps	fiscal	116	eadr
direct	129	eald	talk	154	atad
chief	119	ypest	daily	122	hots
needs	152	asedb	series	130	ivesg
spring	127	ityqual	hold	169	tages
charge	122	oldc	reached	169	sidein
radio	120	lierear	march	120	oorp
medical	162	edadd	defense	167	eadd
ones	116	inef	justice	114	ensev
walked	159	sweran	amount	172	allb
learned	117	telho	game	123	rthea
passed	157	tocks	issue	152	ilesm
degree	125	sultsre	letters	115	inglook
feed	123	cludein	writing	117	eavyh
corner	115	terlat	note	127	oolp
entire	149	ingdo	normal	136	arsc
rest	163	rexssp	choice	113	tays
food	147	dowwin			
steps	119	bersnum			
tried	170	nalfi			
foreign	158	plecou			
appear	118	allh			
simple	161	lubc			
hundred	171	entc			
doubt	114	howns			
born	113	orseh			
purpose	149	ketmar			
lived	115	earh			
getting	164	lansp			
lower	123	deedin			
range	160	countac			
stand	148	arthe			
groups	125	engthl			
natural	156	ningrun			
basic	171	earf			
growth	155	ormsf			
care	162	erveds			
efforts	127	turepic			
moving	114	lyslow			
pattern	113	ainm			
respect	125	tralcen			
start	154	plysim			

APPENDIX B. WORD AND LETTER STRING NONWORD RECOGNITION TESTS USED IN EXPERIMENTS 1 & 2

Word Recognition Test 1:

Please circle the words below that are prospective cues.

WAITING	GIRLS
FAITH	BRIDE
HOSPITAL	MEMBER
HUSBAND	BROWN
DROPPED	GIVES
BALL	DECIDED
CONCERN	BEYOND
REPORT	MASS
HOURS	BLUE
EXTENT	DEEP

Word Recognition Test 2:

<u>Please circle the words below that are prospective cues.</u>

MEMBER	MASS
HUSBAND	BEYOND
HOURS	EXTENT
GIVES	BRIDE
HOSPITAL	REPORT
FAITH	WAITING
CONCERN	BALL
DEEP	DROPPED
BLUE	BROWN
GIRLS	DECIDED

Letter String Nonword Recognition Test 1:

<u>Please circle the nonwords below that are prospective cues</u>

ONEN	NALLYFI
HANGESC	CILCOUN
UMEVOL	VENTSE
RITEW	EEKSW
LYHARD	LOSEDC
EETHT	LOWBE
FECTSEF	LAYEDP
EEPD	HAMPC
INGLIV	EETM
HIRDT	UESVAL

Letter String Nonword Recognition Test 2:

Please circle the nonwords below that are prospective cues

UMEVOL	RITEW
HANGESC	EETM
UESVAL	HAMPC
HIRDT	EEPD
FECTSEF	CILCOUN
LOSEDC	INGLIV
LAYEDP	EETHT
NALLYFI	ONEN
EEKSW	LOWBE
LYHARD	VENTSE

APPENDIX C. STIMULI USED IN EXPERIMENT 2

LIST 1				LIST 2			
words	freq	$nonwords_{ls}$	$nonwords_{on}$	words	freq	$nonwords_{ls}$	$nonwords_{on}$
length	116	wardfor	sere	forward	115	nercor	lombs
account	117	riousse	for a	serious	116	neso	hever
horse	117	reeng	tifted	green	116	edlearn	nowed
window	119	dlemid	plip	middle	118	pearap	moft
main	119	estt	plaws	test	119	tepss	varring
based	119	ageim	cucking	image	119	hiefc	pult
served	120	loodb	bes	blood	121	diora	galm
couple	122	opst	notel	stop	120	hargec	frows
running	123	gerlar	furly	larger	123	eedf	pangle
numbers	125	riedcar	garted	carried	125	erlow	penders
hotel	126	armf	tolk	farm	125	greede	nolt
fear	127	lantp	geans	plant	125	roupsg	slutter
press	127	lacedp	dras	placed	126	spectre	henders
forms	128	ingmean	pic	meaning	127	fortsef	dulks
lead	129	domfree	tealing	freedom	128	prings	spooting
average	130	selfmy	ceared	myself	129	lyclear	prem
chance	131	ausec	raste	cause	130	rectdi	trag
step	131	merfor	teels	former	131	iecep	plat
friend	133	myar	stipped	army	132	onthm	slares
size	138	istl	mung	list	133	ningeve	cye
anyone	140	mersum	amd	summer	134	aless	vandy
deal	142	tionna	sumping	nation	139	lynear	gitch
points	143	dingrea	fards	reading	140	deasi	natter
hour	144	howeds	nilled	showed	141	quares	daint
club	145	dyrea	plazed	ready	143	aidp	kerry
earlier	146	terlet	demp	letter	145	oodf	taves
stock	147	asesc	herges	cases	148	tands	povers
results	149	borla	finners	labor	149	posepur	yure
earth	150	lylike	crasp	likely	151	tireen	daster
answer	152	torys	breat	story	153	eedsn	prawl
hall	152	tycoon	towls	county	155	tarts	slet
hear	153	licepo	mooked	police	155	rowthg	tumped
market	155	liarsim	boted	similar	157	uralnat	shof
final	156	loorf	joiled	floor	158	assedp	bapping
cent	158	ringb	yelting	bring	158	eignfor	slocks
picture	162	ingmeet	cumble	meeting	159	alkedw	narry
fine	161	allw	glanted	wall	160	ngera	yarry
indeed	162	jectsub	gooked	subject	161	plesim	fote
doing	163	riendsf	linning	friends	162	icalmed	finc
central	164	ermst	hordy	terms	163	arec	snam

LIST 3				LIST 4			
words	freq	$nonwords_{ls}$	$nonwords_{on}$	words	freq	$nonwords_{ls}$	$nonwords_{on}$
corner	115	sueis	spone	plans	113	engthl	losting
ones	116	alkt	larp	include	113	countac	gandy
learned	117	perpa	cripped	quality	114	orseh	lerk
appear	118	erhigh	lailing	shown	166	dowwin	nist
steps	119	ingtry	firth	simply	170	ainm	lem
chief	119	mounta	hoal	latter	114	asedb	suh
radio	120	yheav	clope	slowly	115	serveds	detter
charge	122	texten	rivel	types	116	plecou	stimmer
feed	123	smas	wisa	cold	171	ningrun	nath
lower	123	kspea	leny	added	172	bersnum	vangs
degree	125	lsee	peads	parts	113	telho	rorn
groups	125	uresfig	anto	figures	113	earf	haxes
respect	125	lanep	hince	plane	114	ressp	chames
efforts	127	signde	graper	design	114	ormsf	hoil
spring	127	clearnu	blund	nuclear	115	eadl	summy
clearly	128	orts	catting	sort	164	erageav	hunged
direct	129	erriv	ratching	river	165	hancec	clant
piece	129	landis	vath	island	167	teps	bounted
month	130	ovem	trake	move	171	riendf	frint
evening	133	glesin	gly	single	172	izes	dushy
sales	133	ternpat	fushes	pattern	113	yonean	pucking
nearly	141	ornb	yops	born	113	eald	blass
ideas	143	ingmov	gresses	moving	114	ointsp	abose
square	143	oubtd	tobes	doubt	114	ourh	wries
paid	145	ivedl	vapped	lived	115	lubc	faunted
food	147	estr	vinger	rest	163	lierear	fashed
stand	148	tinget	pellow	getting	164	tocks	haped
purpose	149	riedt	lounding	tried	170	sultsre	runted
entire	149	dredhun	caths	hundred	171	arthe	jares
needs	152	sicba	werve	basic	171	sweran	sivers
start	154	archm	teaving	march	120	allh	veek
growth	155	lydai	shaly	daily	122	earh	swug
natural	156	terslet	scook	letters	115	ketmar	pards
passed	157	calfis	paller	fiscal	116	nalfi	harsy
foreign	158	ingwrit	amt	writing	117	entc	jir
walked	159	fensede	dought	defense	167	turepic	denk
range	160	oldh	zeer	hold	169	inef	ceared
simple	161	eachedr	gropping	reached	169	deedin	loody
medical	162	ticejus	doming	justice	114	ingdo	torb
care	162	hoicec	blinging	choice	113	tralcen	recks

LIST 5			
words	freq	nonwords_{ls}	nonwords_{on}
game	123	lansp	bince
easy	125	cludein	suzzle
note	127	ityqual	spir
series	130	howns	sotter
opened	131	plysim	tustle
normal	136	lyslow	keach
method	142	ypest	horry
sent	145	oldc	kives
fall	147	edadd	sheel
issue	152	terlat	ralled
talk	154		
paper	157		
higher	160		
trying	163		
amount	172		
heavy	110		
extent	110		
mass	110		
speak	110		
else	176		

APPENDIX D. NEIGHBOR NONWORD RECOGNITION TESTS USED IN EXPERIMENT 2

Neighbor Nonword Recognition Test 1:

<u>Please circle the nonwords below that are prospective cues</u>

WUNS	SPUNT
DUSHY	BOUNTED
BLASS	BICKLE
VAGES	LOSTING
JASHED	GANDY
LENY	DEACHES
HINCE	GRAPER
BORM	SPOOTING
NOLT	POVERS
DULKS	GLAYING

Neighbor Nonword Recognition Test 2:

Please circle the nonwords below that are prospective cues

BICKLE	JASHED
RORN	DEACHES
STIMMER	VANGS
WUNS	DETTER
SWUG	JARES
BLUND	ANTO
PALLER	BORM
SPUNT	FUSHES
GLAYING	YOPS
GRESSES	VAGES

APPENDIX E. STIMULI USED IN EXPERIMENT 3

LIST 1					
words	freq	nonwords	words	freq	nonwords
council	103	eredcov	size	138	mersum
ball	110	calfis	anyone	140	tionna
pool	111	ingwrit	deal	142	dingrea
plans	113	artsp	points	143	howeds
include	113	uresfig	hour	144	dyrea
staff	113	chinema	club	145	terlet
seven	113	ighte	earlier	146	asesc
quality	114	lanep	stock	147	borla
latter	114	signed	results	149	lylike
slowly	115	clearnu	earth	150	torys
types	116	wardfor	answer	152	tycoun
length	116	riousse	hall	152	licepo
account	117	reeng	hear	153	ilarsim
horse	117	dlemid	market	155	loorf
window	119	estt	final	156	ringb
main	119	ageim	cent	158	ingmeet
based	119	loodb	fine	161	jectsub
served	120	opst	picture	162	allw
couple	122	gerlar	indeed	162	riendsf
running	123	riedcar	doing	163	ermst
numbers	125	armf	central	164	orts
hotel	126	lantp	shown	166	erriv
fear	127	lacedp	simply	170	landis
press	127	ingmean	cold	171	ovem
forms	128	domfree	added	172	glesin
lead	129	selfmy	earth	173	hoicec
average	130	ausec	data	173	ticejus
chance	131	merfor	stage	174	terslet
step	131	myar	dead	174	pitedes
friend	133	istl	coming	174	rentcur

LIST 2					
words	freq	nonwords	words	freq	nonwords
machine	103	archm	list	133	ningeve
eight	104	oten	summer	134	agless
despite	104	riesse	nation	139	lynear
cars	112	odmeth	reading	140	deasi
gives	112	ents	showed	141	quares
parts	113	ternspat	ready	143	aidp
figures	113	ornb	letter	145	oodf
stay	113	penedo	cases	148	tands
plane	114	ingmov	labor	149	posepur
design	114	oubtd	likely	151	tireen
nuclear	115	ivedl	story	153	eedsn
forward	115	nercor	county	155	artst
serious	116	neso	police	155	rowthg
green	116	edlearn	similar	157	uralnat
middle	118	pearap	floor	158	assedp
test	119	tepss	bring	158	eignfor
image	119	hiefc	meeting	159	alkedw
stop	120	hargec	wall	160	ngera
blood	121	diora	subject	161	plesim
larger	123	eedf	friends	162	icalmed
carried	125	erlow	terms	163	arec
farm	125	greede	sort	164	estr
plant	125	roupsg	river	165	tinget
placed	126	spectre	island	167	riedt
meaning	127	fortsef	move	171	redhun
freedom	128	prings	single	172	sicba
myself	129	lyclear	lost	173	lydai
cause	130	rectdi	instead	173	ameg
former	131	iecep	inside	174	syea
army	132	onthm	father	183	malnor

LIST 3					
words	freq	nonwords	words	freq	nonwords
heavy	110	eachedr	evening	133	riendf
extent	110	mounta	sales	133	izes
faith	111	perpa	nearly	141	yonean
shot	112	erhigh	ideas	143	eald
pattern	113	lansp	square	143	ointsp
born	113	cludein	paid	145	ourh
saying	113	ingtry	food	147	lubc
poor	113	fensede	stand	148	lierear
moving	114	ityqual	purpose	149	tocks
doubt	114	terlat	entire	149	sultsre
lived	115	lyslow	needs	152	arthe
corner	115	ypest	start	154	sweran
ones	116	engthl	growth	155	allh
learned	117	countac	natural	156	earh
appear	118	orseh	passed	157	ketmar
steps	119	dowwin	foreign	158	nalfi
chief	119	ainm	walked	159	entc
radio	120	asedb	range	160	turepic
charge	122	erveds	simple	161	inef
feed	123	plecou	medical	162	deedin
lower	123	ningrun	care	162	ingdo
degree	125	bersnum	rest	163	tralcen
groups	125	telho	getting	164	howns
respect	125	earf	tried	170	plysim
efforts	127	ressp	hundred	171	oldc
spring	127	ormsf	basic	171	edadd
clearly	128	eadl	read	173	allf
direct	129	erageav	miles	173	sueis
piece	129	hancec	looking	173	alkt
month	130	teps	report	174	oldh

LIST 4		
words	freq	nonwords
station	105	vatepri
season	105	ergyen
married	105	tordoc
choice	113	eadr
justice	114	ilesm
letters	115	inglook
fiscal	116	ostl
writing	117	steadin
march	120	rthea
daily	122	atad
game	123	tages
easy	125	portre
note	127	sidein
series	130	eadd
opened	131	ingcom
normal	136	eavyh
method	142	tentex
sent	145	allb
fall	147	oolp
issue	152	aithf
talk	154	otsh
paper	157	ivesg
higher	160	arsc
trying	163	taffs
defense	167	tays
hold	169	ensev
reached	169	ingsay
amount	172	oorp
return	180	ookb
wrote	181	cilcoun

APPENDIX F. RECOGNITION TESTS USED IN EXPERIMENT 3

Two Cue Recognition Test 1:

Please circle the words that are prospective cues

ENTIRE	MASS
MEDICAL	BEYOND
HOURS	EXTENT
GIVES	BRIDE
HOSPITAL	REPORT
FAITH	WAITING
CONCERN	BALL
DEEP	DECIDED
READ	BROWN
GIRLS	HUNDRED

Two Cue Recognition Test 2:

Please circle the words that are prospective cues

WAITING	GIRLS
FAITH	BRIDE
HOSPITAL	ENTIRE
HUNDRED	BROWN
DROPPED	GIVES
BALL	DECIDED
CONCERN	BEYOND
REPORT	MASS
HOURS	READ
EXTENT	DEEP

Six Cue Recognition Test 1:

<u>Please circle the words that are prospective cues</u>

BOYS	RECORD
COUNCIL	SCIENCE
START	BASIC
MAYBE	HUSBAND
RIVER	FATHER
MOVE	BLUE
FORMER	MILES
INSIDE	NATION
ARMY	MEETING
BELOW	MEMBER

Six Cue Recognition Test 2:

Please circle the words that are prospective cues

BELOW	FATHER
MOVE	BASIC
SCIENCE	RIVER
ARMY	MILES
START	BLUE
RECORD	HUSBAND
COUNCIL	FORMER
BOYS	MEMBER
INSIDE	MEETING
MAYBE	FORMER

APPENDIX G. SURPRISE RECOGNITION TESTS FOR EXPERIMENT 1

Surprise Recognition Test for PM_w cues

Please circle the words that were prospective cues

IMAGE	PURPOSE
BLUE	INDEED
ENTIRE	BLOOD
NEEDS	SERIES
BOYS	SHOWN
CENTRAL	RECORD
CENT	MIDDLE
FOOD	DOING
MORAL	NEITHER
TEST	DECIDED
EASY	STUDENT
HUSBAND	SERIOUS
OPENED	MEMBER
STAND	GIRLS
PICTURE	GREEN

Surprise Recognition Test for PM_{nw} cues

<u>Please circle the nonwords that were prospective cues</u>

EETM	LYMERE
SINGU	DIORA
ORTS	ENGTHL
PLECOU	ERVEDS
ORSEH	AIRH
HANGESC	LANDIS
ENCESCI	ERLOW
COUNTAC	EEKSW
LOWBE	EEDSN
UMEVOL	URESFIG
JECTSUB	ASEDB
RIENDSF	HARGEC
EEDF	TENTEX
ERMST	HIEFC
DOWWIN	OOLP

APPENDIX H. SURPRISE RECOGNITION TESTS FOR EXPERIMENT 2

Surprise Recognition Test for PM_w cues

<u>Please circle the words that were prospective cues</u>

IMAGE	PURPOSE
BLUE	INDEED
ENTIRE	BLOOD
NEEDS	SERIES
BOYS	SHOWN
CENTRAL	RECORD
CENT	MIDDLE
FOOD	DOING
MORAL	NEITHER
TEST	DECIDED
EASY	STUDENT
HUSBAND	SERIOUS
OPENED	MEMBER
STAND	GIRLS
PICTURE	GREEN

Surprise Recognition Test for PM_{LS} cues

<u>Please circle the nonwords that were prospective cues</u>

EETM	LYMERE
SINGU	DIORA
ORTS	ENGTHL
PLECOU	ERVEDS
ORSEH	AIRH
HANGESC	LANDIS
ENCESCI	ERLOW
COUNTAC	EEKSW
LOWBE	EEDSN
UMEVOL	URESFIG
JECTSUB	ASEDB
RIENDSF	HARGEC
EEDF	TENTEX
ERMST	HIEFC
DOWWIN	OOLP

Surprise Recognition Test for PM_{ON} cues

<u>Please circle the nonwords that were prospective cues</u>

FRINT	CUCKING
CLANT	PLAWS
TIFTED	BORM
RASTE	SUMPING
VAGES	GLAYING
DEACHES	KERRY
SPUNT	GITCH
HARSY	TORB
CEARED	JARES
HUNGED	DOUGHT
GROPPING	ZEER
SCOOK	HENDERS
YARRY	JASHED
PRAWL	SHOF
GOOKED	FARDS

APPENDIX I. SURPRISE RECOGNITION TESTS FOR EXPERIMENT 3

Surprise Recognition Test for PM Cues

Please circle the words that were prospective cues

IMAGE	SCIENCE
BLUE	INDEED
ENTIRE	BLOOD
NEEDS	SERIES
BOYS	SHOWN
CENTRAL	RECORD
CENT	MAYBE
FOOD	BELOW
MORAL	NEITHER
TEST	DECIDED
EASY	STUDENT
HUSBAND	SERIOUS
OPENED	MEMBER
STAND	GIRLS
PICTURE	GREEN